Advance Sheets, No. 5 Issued March 15, 1922

UNITED STATES DEPARTMENT OF AGRICULTURE
OFFICE OF FARM MANAGEMENT
H. C. TAYLOR, Chief

ATLAS OF AMERICAN AGRICULTURE

Prepared under the Supervision of O. E. BAKER, Agriculturist

PART II
CLIMATE

Contribution from the U. S. Weather Bureau, CHARLES F. MARVIN, Chief

SECTION A
PRECIPITATION AND HUMIDITY

Prepared under the Direction of P. C. DAY, Climatologist

BY

J. B. KINCER
Meteorologist, U. S. Weather Bureau

WASHINGTON
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Figure A.—This map shows the location and relative density in different sections of the country of the Weather Bureau stations whose records were compiled and used in the preparation of all of the precipitation maps, except where otherwise specified. The location of the 200 regular, full-reporting Weather Bureau stations, whose records were used in the preparation of figures 66, 69, 70, 75, 77, 79, 80, 81, 82, 83, and 84, is shown by a hollow circle. The location of the cooperative stations, whose records were used in addition to those of the regular Weather Bureau stations in the preparation of the annual, seasonal, and monthly precipitation maps and the snowfall map, is shown by a red dot. The more important mountain ranges and river valleys are also shown on this map by means of hachuring. These physiographic features exercise an important influence over the distribution of precipitation.

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PRECIPITATION AND HUMIDITY.

PRECIPITATION includes rain, melted snow, sleet and hail. The standard U. S. Weather Bureau rain gauge is installed at all stations whose records were used in preparing the precipitation maps in this section of the Atlas.

SOURCE OF DATA.—Records for the uniform 20-year period 1895 to 1914 form the basis of all the principal charts and diagrams. During these 20 years weather observations have been extended into nearly all portions of the country, which permits more exact deductions regarding the comparative distribution of precipitation than have heretofore been possible. The stations having records for the full 20-year period number only about 1,600; hence additional shorter records have been used from about 2,000 other stations. These shorter records lie within the same period, 1895–1914, and vary in length from 10 to 19 years, except for some of the less developed sections of the far West, where, owing to the limited data available, a few records of under 10 years have been used.

A few of the long records have occasional short breaks, and these records have been completed by interpolating the missing values, considering for that purpose the records of near-by stations. The reduction of the short records to the uniform 20-year period has been accomplished by comparing their values with those made at near-by long-record stations during the periods the short-record stations were in operation and applying the ratios for the short periods to the 20-year averages of the long-record stations. As a rule, each short record was compared with two or more near-by records covering the full period, and the results averaged.

No such extensive compilation of precipitation data has previously been undertaken by the Weather Bureau nor has it been possible heretofore, on account of lack of observations, to show so accurately the local details and variations of this important climatic element in the more recently developed portions of the country and at the higher altitudes in the West.

Cooperative observers' records.—Of the 3,600 records used in the preparation of the charts, about 200 were made at the regular observing stations of the Weather Bureau, and the others by cooperative and special observers, mostly the former. Thus the accumulation of the large amount of data necessary for the preparation of these charts has been made possible only by the cooperation of public-spirited citizens in every section of the country, who have taken and recorded for many years daily observations of the amount of precipitation. Most of these records cover the full 20-year period without a break, and many were made during the entire time by the same observer. They were made under the supervision of, and have been carefully checked by, trained officials of the Climatological Service of the Weather Bureau, which insures that they represent actual conditions as nearly as these can be determined. After the shorter records were reduced to the full 20-year period, and all averages computed, the data were plotted on large topographic maps, upon which lines were then drawn indicating areas having approximately equal amounts of precipitation. These large maps were then finally reduced to the dimensions shown in the accompanying charts. The uniform agreement of the data as shown by the figures for adjacent stations indicates that the observations at the several classes of stations, mostly cooperative, were made with remarkable accuracy.

Geographic distribution of stations.—Precipitation data can be satisfactorily shown for an extended area, such as the United States, only by means of charts based on averages for a definite period of sufficient length to give dependable results, and for a sufficient number of points to represent every section of the country (see fig. A). East of the Rocky Mountains these conditions are more or less fully met by available data in practically all localities, except that in some portions of the Appalachian Mountains more observations are needed. From the Rocky Mountains westward, however, no actual precipitation measurements for many of the more elevated and less accessible localities are available. It is now possible, however, to determine the amount of precipitation in those regions with assurance of a much greater degree of accuracy than has been possible heretofore owing to the fact that a considerable number of snowfall stations have been maintained in the higher mountains by the Weather Bureau for several years. The records from these stations are now available and have been used in the preparation of the accompanying charts. These records have been found especially valuable in studying the variations of precipitation with altitude in different localities and under different topographic and geographic surroundings and as an aid in drawing isohyetal lines through similar regions where few or no gauge records are available.

PRESENTATION OF DATA.—In a publication of this character the presentation of data must necessarily be largely in the form of charts and graphs showing average conditions, but at the same time it is recognized that the value of such charts is greatly enhanced by supplementary maps and diagrams showing the variations from the average which may be expected from time to time and other noteworthy features. Therefore a number of auxiliary maps and graphs have been included.

Construction of the charts.—Owing to the existence of many and diverse factors operating to control the occurrence of precipitation, and the large variations in amounts frequently resulting, even in limited geographic areas, the problem of depicting by graphic means the actual amount of precipitation for the entire United States is one of considerable difficulty. The drawing of the isohyetal lines from station to station necessarily involves interpolations. Over relatively smooth land surfaces and for areas well represented by records these interpolations are not difficult to accomplish, but for mountainous regions where few precipitation measurements have been made, as in portions of our Western States, the process becomes more complex. Opinions differ as to the best procedure in attempting to depict the amount of precipitation in the absence of actual measurements. It is self-evident that precipitation charts can not show complete details for such regions, but at the same time users of these charts require that they show the probable conditions as nearly as it is possible to determine them.

Owing to the recent development of farming operations under irrigation in many of the fertile but arid valleys of the West, the question as to the amount of precipitation occurring at the higher elevations has become of great importance, as the flow of streams and hence the water available for irrigation is largely dependent upon mountain snowfall. It is especially important, therefore, to show normal conditions existing in these higher altitudes as nearly as possible, and a chart which omits details necessary for this purpose does not meet present-day requirements. For example, in the preparation of precipitation charts it may be literally correct to mark areas "20 inches plus" where 40 inches occur, but such a practice would be misleading and would not serve the purposes for which such charts are intended.

In drawing isohyetal lines for these less accessible regions, actual measurements, of course, should be the basis, but where few such observations have been made it is better to supplement the available data by such other evidences as may be at hand. Among these may be mentioned the known increase in precipitation with elevation, the character of vegetation, and the stream flow, in so far as these have been determined.

The accompanying charts have been constructed in accordance with these principles, and it is believed they present as accurate a picture of the general precipitation conditions as can be made from the available data.

Relative utility of the several charts.—Existing charts of average precipitation for the United States have been prepared mostly for the entire year, although there are a few for the summer half-year only, April–September. The principal difficulties in the application of statistics of annual precipitation arise, first, because there is always the possibility that, owing to the long period covered, large deficiencies in portions of the year, especially disastrous droughts in the season of critical plant development, may be concealed by excess precipitation at other times of year; and, second, because the annual amount gives no information as to seasonal distribution, which agriculturally is of great importance. For example, the eastern portion of South Dakota receives on the average between 20 and 25 inches of precipitation annually. This amount may or may not be sufficient for the successful prosecution of agricultural enterprises by ordinary farming methods, depending wholly on its seasonal distribution and the locality. The amount is sufficient in South Dakota, owing to its concentration in the growing season and the comparatively low rate of evaporation, but with a uniform seasonal distribution and more rapid evaporation it would be inadequate.

The charts of monthly precipitation also are not entirely satisfactory for many purposes, owing to the relatively large fluctuations in the monthly amounts, while the averages are sometimes unduly magnified by the occurrence of a few very heavy rainfalls which have little agricultural value.

Seasonal charts are less subject to the limitations mentioned for monthly and annual charts and are, therefore, better representations of precipitation in its relation to agriculture. Consequently, five double-page charts are presented, namely, one for the warm season, April to September, inclusive, and one for each of the four seasons, winter, spring, summer, and fall (figs. 8, 20, 30, 40, and 50). As a basis for the study of the relation of precipitation to agriculture the importance of these charts can scarcely be overemphasized.

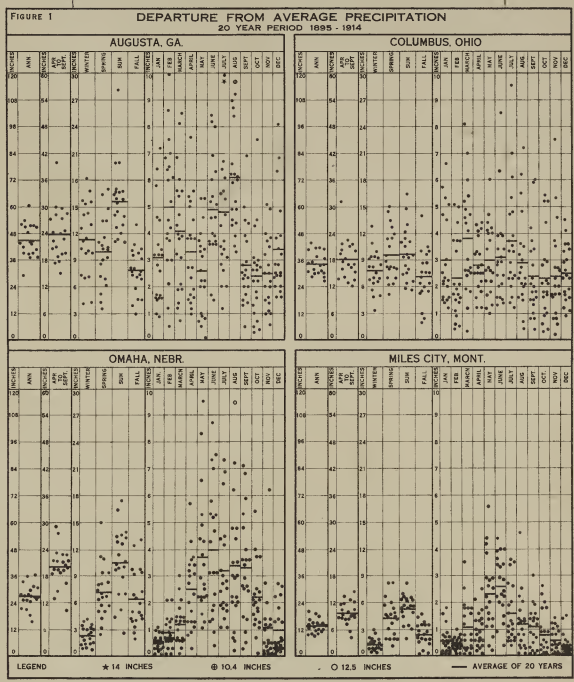

Figure 1.—Comparison of the dispersions of the annual, seasonal, and monthly precipitation about the average at selected stations for the 20 years, 1895–1914. The scales are drawn on a comparable basis—that is, the scale for the half year, comprising the warm season, is twice as large as the annual, each of the 4 seasons 4 times as large, and each of the 12 months 12 times as large. These graphs show the relative variations from the average that are likely to occur for the several periods covered by the various precipitation charts, and emphasize the tendencies to increasingly greater departures from the average with the decreasing length of the period covered. A dot represents the annual, seasonal, or monthly precipitation, as the case may be, for each year, and the heavy horizontal bars show the 20-year averages.

At the bottom of each of these charts is presented a graph which shows for a number of representative localities the seasonal precipitation for each of the 20 years on which the chart is based. On these graphs the amount for the season in each year is represented by a dot, the location of which shows the amount, and the mean of the values represented by the 20 dots for each station corresponds to the basis for the isohyetal lines of the large chart. These graphs show for different localities the variations in the seasonal amounts of precipitation likely to occur from year to year, and give an indication of the relative dependability of the means for different sections of the country.

Dependability of 20-year averages.—As the precipitation charts are based on averages covering the 20-year period 1895 to 1914, it is of importance to inquire as to their dependability; that is, would any other 20-year period likely show materially different results? A period of 20 years, admittedly, is not of sufficient length to give average values of precipitation that would not be changed by the addition of records for succeeding years, but a study of the available records has shown that the period is long enough to give average values sufficiently accurate for use in studying the distribution of precipitation as affecting agricultural enterprises. In this respect the future can be judged only from the past, and as an indication of the changes in the amounts of precipitation that may be expected from year to year during long periods of time, the annual amounts are shown in figure 6 for several stations having long records. The record for New Bedford covers 101 years, 1814 to 1914; that for Marietta 93 years; and the records for Oregon, Mo., Manhattan, Kans., Boise, Idaho, and Sacramento, Cal., are each 50 years in length. In these cases the averages for the 20-year period 1895 to 1914, as must be expected, differ somewhat from those of other periods of equal length, but it will be seen that the differences are not large enough to be of material agricultural significance.

Much has been written on the subject of secular variations in the amount of precipitation and so-called cyclical fluctuations, but the records in this country are too short to give any definite indications of these fluctuations. The longest records available cover a period of about 100 years, and a considerable number of stations have records ranging in lengths from 50 to 60 years. While a study of these records shows more or less definite and recognizable long-period fluctuations, they appear to be largely localized and no definite conclusions can be drawn for any area of considerable extent.

The long-period fluctuations are shown for the six stations comprising figure 6 by superposed curves, smoothed by the formula $\frac{a+4b+6c+4d+e}{16}=c'$, where c' is an adjusted average for the middle year of the series. This serves to reduce factors purely temporary and emphasizes tendencies extending over several years. So far as the available data indicate, the amount of rainfall in this country is neither permanently increasing nor decreasing in any locality.

Variations from average values.—The significance that attaches to an average made up of variables of different magnitudes depends on the nature of the dispersion of the variables about the average. If the individual

Figure 2.—This chart shows the average annual precipitation in different sections of the United States. East of the Rocky Mountains lines are drawn for each 5-inch interval, but in some of the mountainous districts of the West wider intervals had to be used. On the basis of precipitation, the United States may be divided into an eastern and a western part, the dividing line following approximately the 100th meridian, in the vicinity of which, from Canada to Mexico, the average annual precipitation is about 20 inches. In general, the eastern part has sufficient precipitation for successful farming by ordinary methods, but in the western part the amount of moisture over large areas is insufficient for the requirements of crop growth and here special methods of supplying moisture to or conserving it in the soil are often employed. Some of the principal features of the geographic distribution of precipitation in the United States may be briefly stated as follows: In the Pacific Coast States great differences in precipitation obtain, the average annual amounts ranging from more than 120 inches in portions of western Washington to less than 5 inches in the extreme southeastern portion of California. These localities represent the extremes of moisture conditions found in the United States. In the Interior Plateau region precipitation is scanty and generally insufficent for ordinary farming operations. At the lower altitudes the average amounts range from less than 5 to about 10 inches, the larger amounts appearing mostly in the northern districts. Somewhat heavier precipitation occurs at the higher altitudes. At the lower altitudes of the Rocky Mountain States there are regions in which the average annual precipitation is less than 10 inches, but at the higher elevations it ranges from 20 to 40 inches, or more. East of the Rocky Mountains precipitation is comparatively uniform over large areas. The average annual amount ranges from about 15 inches along the eastern base of the Rocky Mountains to more than 80 inches in the southern Appalachian Mountains.

Figures 3 and 4.—The inset chart in the lower left hand corner shows the percentage of the annual precipitation which occurs during the six warmer months. In a portion of the Dakotas over 80 per cent occurs during these months, while in California less than 20 per cent is received during this period. The inset graph to the right shows the period of the year during which 50 per cent of the annual precipitation occurs.

FIGURE 5

ANNUAL PRECIPITATION AT SELECTED STATIONS
FOR THE 20 YEAR PERIOD, 1895-1914
ARRANGED BY GEOGRAPHIC DISTRICTS

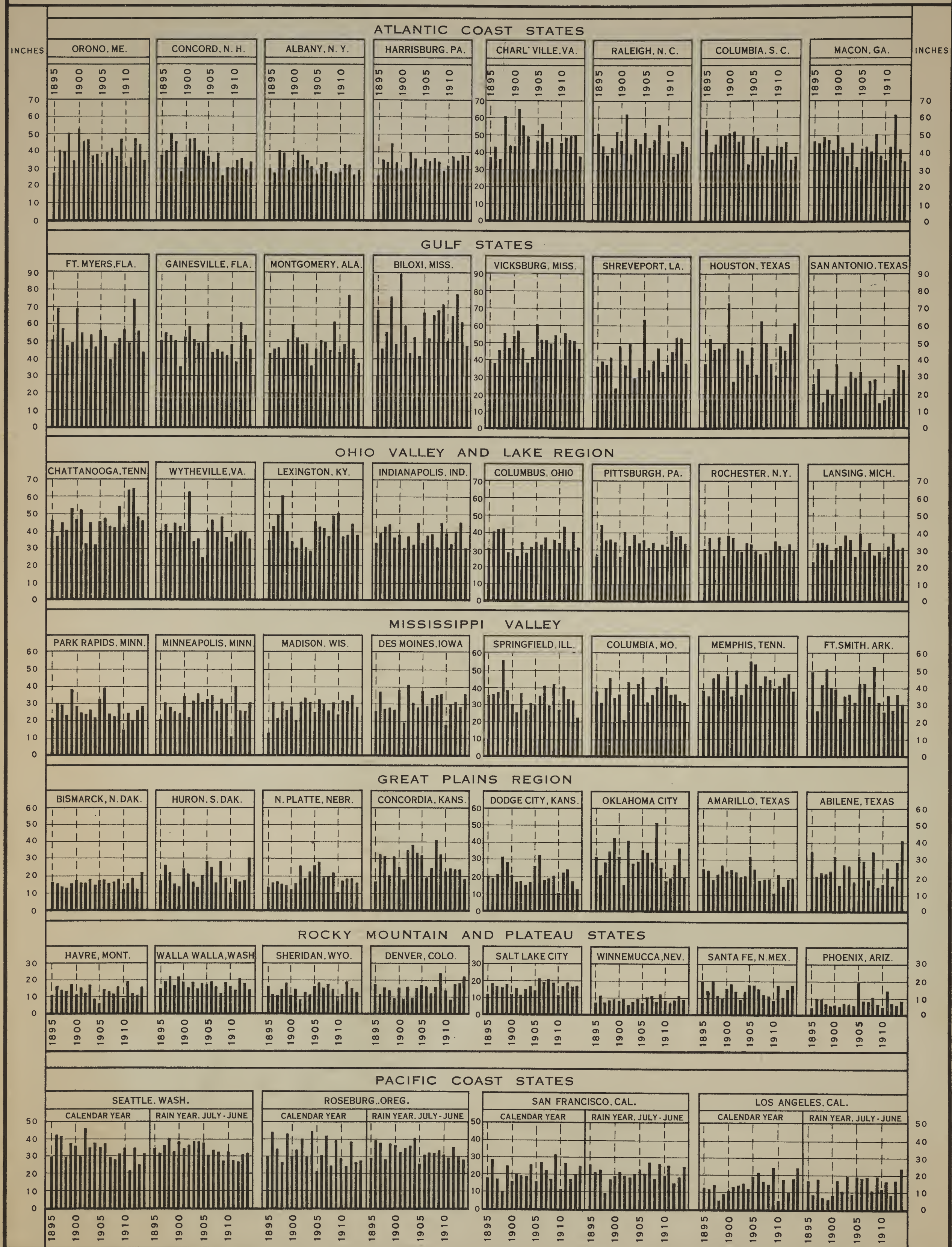

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Figure 5.—These graphs show the annual precipitation at selected stations, arranged by geographic districts, for each of the 20 years from 1895 to 1914, inclusive. The graphs show the variations in the amount of precipitation that may be expected to occur from year to year in the different sections of the country, and also show in a general way the geographic distribution of these variations. The variations are large in the Pacific Coast States and also in the Gulf region and Great Plains States. They are comparatively small in the Ohio and Mississippi valleys. In the Pacific Coast States the precipitation for both the calendar and the rainfall year is shown, the latter covering the period from July 1 to June 30.

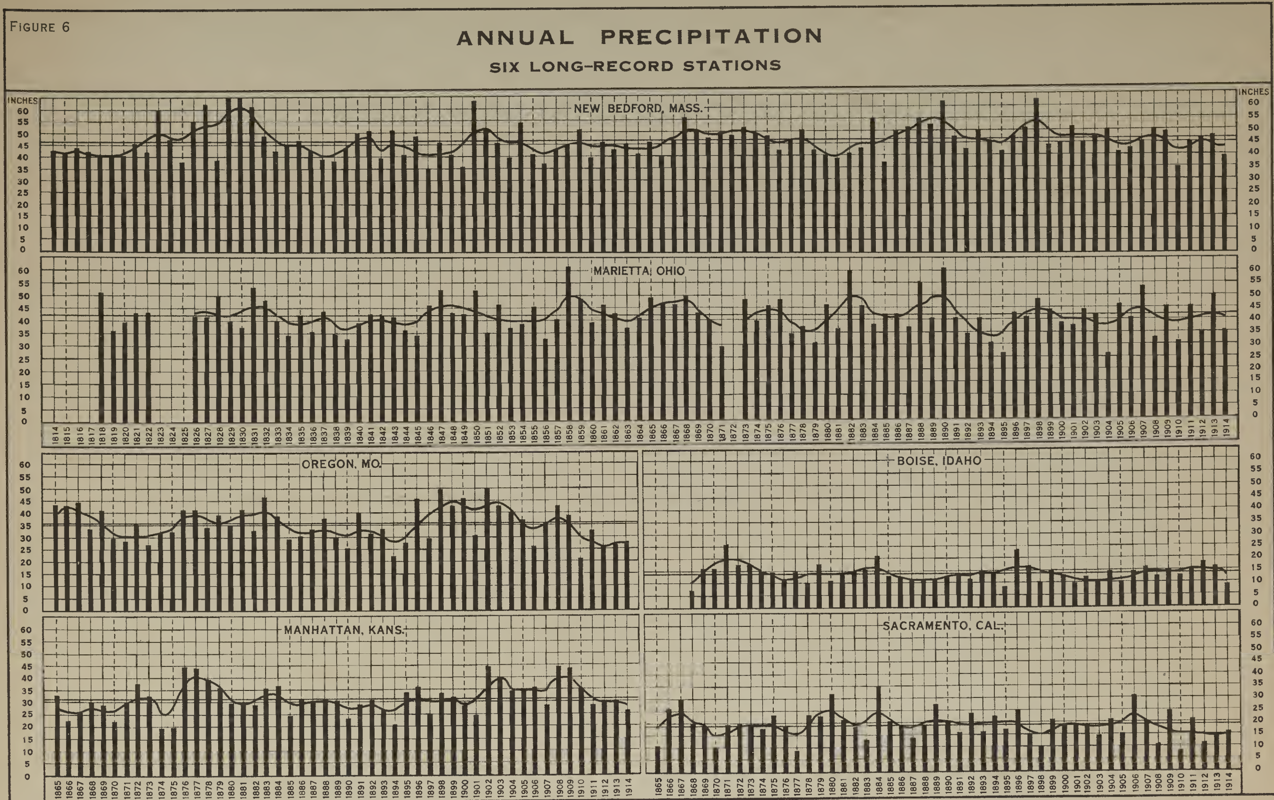


Figure 6.—Annual precipitation at six long-record stations—New Bedford, Mass.; Marietta, Ohio,; Oregon, Mo.; Manhattan, Kans.; Boise, Idaho; and Sacramento, Cal. While a study of the few long records available in this country show more or less definite and recognizable long-period fluctuations in precipitation, these appear to be localized and no definite conclusions can be drawn for any considerable area. The long period fluctuations are shown for these stations by superposed curves, smoothed by the formula $\frac{a+4b+6c+4d+e}{16}=c'$, where c' is the adjusted average for the middle year of the series. This serves to reduce the more or less accidental or temporary factors, and emphasizes tendencies extending over several years. So far as available data indicate, precipitation is neither permanently increasing nor decreasing in any portion of the United States.

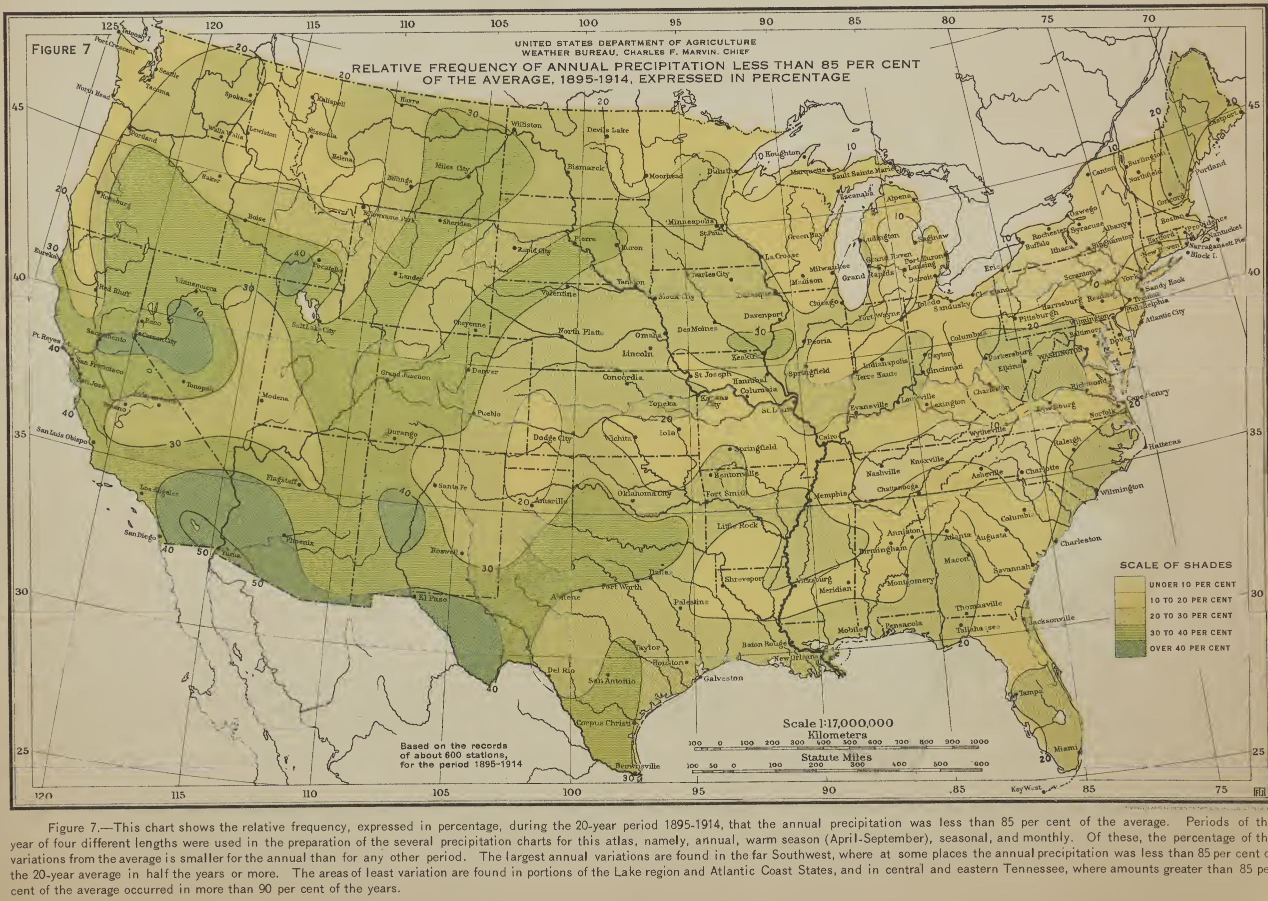


Figure 7.—This chart shows the relative frequency, expressed in percentage, during the 20-year period 1895-1914, that the annual precipitation was less than 85 per cent of the average. Periods of the year of four different lengths were used in the preparation of the several precipitation charts for this atlas, namely, annual, warm season (April-September), seasonal, and monthly. Of these, the percentage of the variations from the average is smaller for the annual than for any other period. The largest annual variations are found in the far Southwest, where at some places the annual precipitation was less than 85 per cent of the 20-year average in half the years or more. The areas of least variation are found in portions of the Lake region and Atlantic Coast States, and in central and eastern Tennessee, where amounts greater than 85 per cent of the average occurred in more than 90 per cent of the years.

Figure 8.—This chart shows the average warm-season precipitation, April to September, inclusive. On the Pacific Coast this is the dry season, and precipitation is light as compared with the other six months of the year. In the Great Plains region, on the other hand, and extending eastward to include Wisconsin, northwestern Illinois, Iowa, northwestern Missouri, and most of Oklahoma, the greater part of the annual precipitation occurs during this period (see fig. 3). East of the Mississippi River and Lake Michigan the seasonal distribution of precipitation is more uniform, except in Florida and along the South Atlantic and Gulf Coasts, where there is a marked summer concentration.

Figures 9 and 10.—The inset chart in the lower left-hand corner shows the percentage of precipitation that occurred at night, 8 p. m. to 8 a. m., 75th meridian time, during the warm season, April to September, inclusive, for the 20-year period, 1895-1914. In some of the interior districts from 60 to 65 per cent of the warm-season rainfall occurs at night, while in some southeastern localities less than 30 per cent of the total occurs during the night hours. The inset graph to the right shows for a number of representative stations, well distributed over the country, the total warm season precipitation that occurred in each of the 20 years whose record was used in preparing the large chart. It indicates the variations in warm season rainfall from year to year in different localities.

Figure 11.—The warm season precipitation is of great agricultural importance, especially in districts east of the Rocky Mountains, and the frequency of material variations from the average for this period is of especial significance. The above chart shows the relative frequency, expressed in percentage, during the 20-year period 1895–1914, that the total precipitation for the warm season, April–September, was less than 75 per cent of the average. The most frequent variations occur in southern California and portions of the adjoining States, where the warm-season rainfall was less than three-fourths of the average in from 8 to 11 years during the 20-year period. However, warm-season rainfall in these districts has little agricultural significance, as the amounts are usually too small for ordinary farming operations. Over the great agricultural districts east of the Rocky Mountains the warm-season precipitation fell below 75 per cent of the average amount in only 2 to 4 seasons during the 20 years.

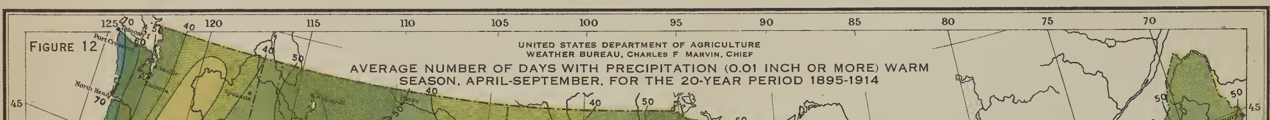


Figure 12.—From the Rocky Mountains westward, except in Arizona and New Mexico during early summer, precipitation generally is of infrequent occurrence during the warm season of the year, April–September, rain falling, as a rule, in fewer than 10 days during the six months in the southern portion of the Pacific Coast States; but to the northward the frequency increases to 70 days along the coast of Washington, occurring largely during April, May, and September. There are also areas of comparatively frequent warm-season rainfall in western Montana and portions of Colorado and Arizona. Over the principal agricultural districts east of the Rocky Mountains, rain occurs on the average between 40 and 60 days during these six warmest months. The areas of most frequent occurrence are in portions of Florida and in the Appalachian Mountain districts, where rain falls on the average on more than 70 days during the period.

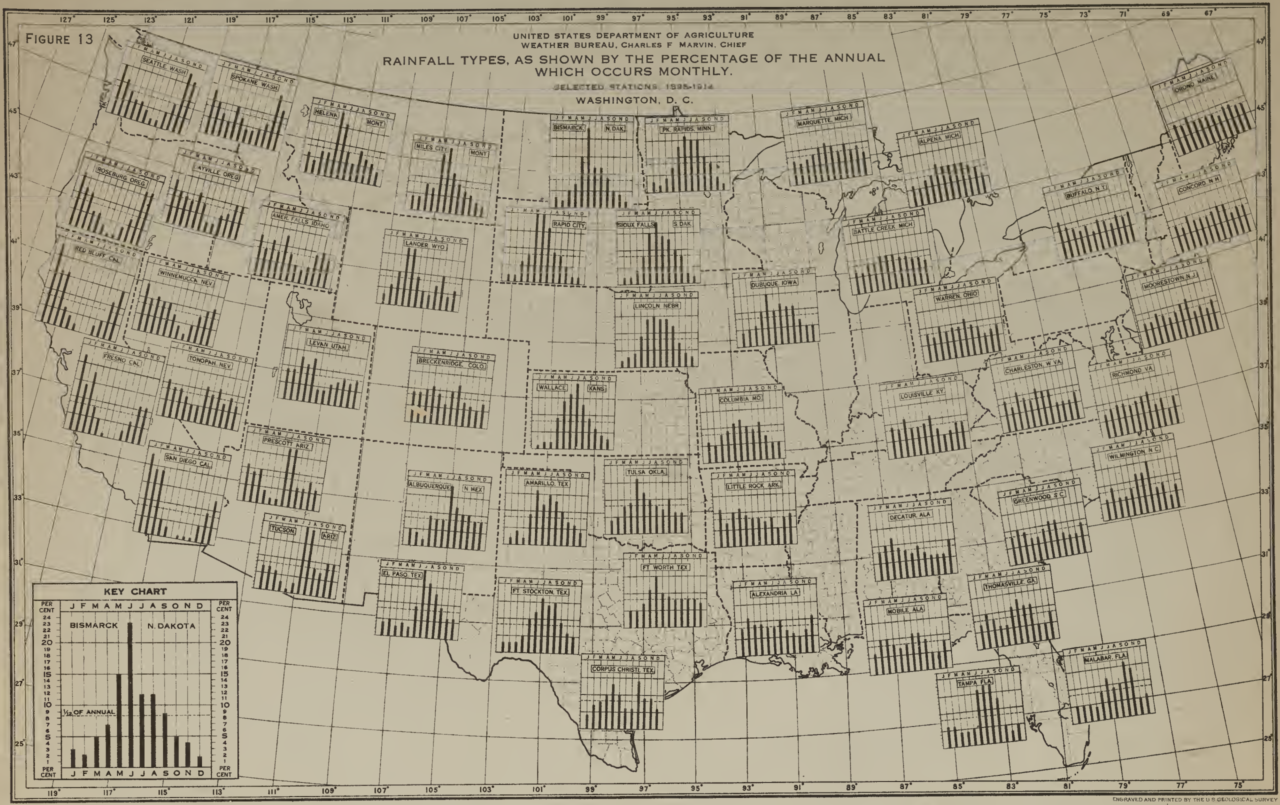


Figure 13.—This chart shows the percentage of the annual precipitation which occurs in each month. Among the several rainfall types that have been recognized in the United States the most noteworthy are the Eastern, Plains, Arizona, Sub-Pacific, and Pacific. Broadly speaking, the Eastern type may be considered as including the originally forested Eastern portion of the United States, except the Florida Peninsula, and is characterized by a comparatively uniform distribution of precipitation throughout the year. The Plains type includes the prairie and plains regions and extends westward to the crest of the Rockies. It is characterized by a marked concentration of rainfall in the late spring and summer months and by dry winters. The Arizona type, which is found in western Texas, New Mexico, and Arizona, is characterized by comparatively heavy rainfall during the months of July and August. In the Sub-Pacific type, which includes most of the country between the Rocky Mountains and the Sierra Nevada and Cascade ranges to the north of the Arizona type, the precipitation occurs mostly during the winter and spring months; while in the Pacific type, which extends westward from the Sierra Nevada and Cascade Mountains to the Pacific Ocean, the winters are wet and the summers are very dry.

values differ but little from the average, the latter is more representative than when wider variations appear.

In the consideration of precipitation charts based on average values for a definite number of years, the variations from year to year should always be taken into account. The nature and magnitude of these variations are, of course, not the same for different sections of the country, nor for different periods of the year. Of the three classes of charts, annual, seasonal, and monthly, the annual has the smallest relative variations, and the monthly the largest, with the seasonal holding an intermediate position. In figure 1 these dispersions about the average are shown in their relation to one another for four representative stations, Augusta, Ga., Columbus, Ohio, Omaha, Nebr., and Miles City, Mont.

The variations of precipitation from year to year are so erratic that no general rule is applicable, except that amounts less than the average usually occur in slightly more than half the years. Therefore, in studying charts showing the average amounts of precipitation, the fact that the amounts shown are usually available for plant development in fewer than half the years should not be lost sight of. Regions having more pronounced variations from year to year, have also proportionately more years in which less than the average amount occurs. This condition is brought about by the fact that in a series of years of sufficient length to give dependable averages there is usually found one or more years with exceptionally heavy rainfall, which may be considered as merely accidental, but which never-the-less raise the average value above the median. In the case of monthly precipitation it is not unusual for a positive departure to be greater than the average itself, but a negative departure of such magnitude obviously can not occur.

The graphs shown in figure 5 indicate for about 50 stations, well distributed throughout the country, the annual precipitation for each of the 20 years, 1895–1914, and also show the variations that occurred from year to year. The graphs in figure 15 show the monthly distribution of precipitation for a large number of representative stations.

The occurrence of minus departures from the average precipitation is usually of greater agricultural significance than plus departures, as most growing plants suffer more frequently from a lack of moisture than from a superabundance. Consequently a number of charts have been prepared showing for the year, the summer half-year, and for each month from March to October, inclusive, the relative number of times in the 20-year period 1895–1914 that the precipitation was less than certain significant percentages of the average. Figure 7 shows the relative number of times the annual amount was less than 85 per cent of the average; figure 11 shows the relative number of times during the warm season that the precipitation was less than 75 per cent of the average; and figures 58 to 65 show for each month from March to October the relative number of times the monthly amount was less than 50 per cent of the average. These charts are based on about 600 records for the uniform 20-year period 1895–1914.

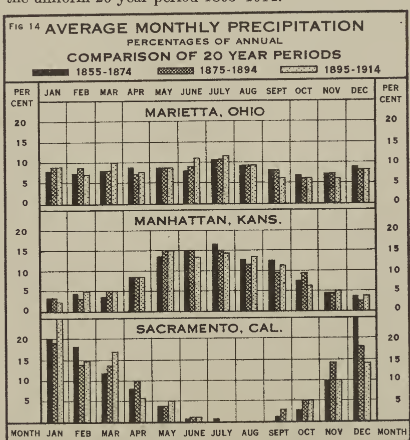


Figure 14.—Average percentages of the annual precipitation that occurred in each month during three successive 20-year periods at Marietta, Ohio, Manhattan, Kans., and Sacramento, Cal., representing the three principal rainfall types in the United States. Solid bars represent the period 1855–1874; closely shaded center bars, 1875–1894; and lightly shaded bars at the right, 1895–1914.

Factors Affecting Precipitation. — Among the many factors which control the geographic distribution of precipitation, the most effective are: Distance from the main sources of moisture supply, oceans, seas, etc., and prevailing surface drift of the air; topographic features, especially differences in elevation and mountain barriers; and location with reference to the most frequent paths of cyclonic storms. In some instances these may operate singly, but in most cases the distribution of precipitation is the result of a combination of several factors.

Influence of large bodies of water.—Whether or not the amount of precipitation decreases with increasing distance from large bodies of water, and whether nearness to the water results in abundant precipitation, depends mostly on the direction of the wind and the temperature conditions. In the United States precipitation is usually heavier near the source of moisture supply, the oceanic influence being clearly indicated by the diminution in precipitation over the successive mountain ranges and valleys with progress inland from the North Pacific Coast. There are, however, some important exceptions; for example, the coast of southern California, where rainfall is scanty, and also the western Gulf Coast, where precipitation as a rule is not greater than over the interior districts to the northward. This geographic distribution has also seasonal variations. During the winter months, for example, the contrast between the average amount of precipitation in the northern interior districts east of the Rocky Mountains, far removed from the source of moisture supply, and that occurring in the central Gulf States, near the supply, is marked, the former, receiving usually less than 1 inch a month and the latter about 4 inches. For the spring and summer months, however, the distribution is more nearly uniform; in fact, in portions of the plains States and in the lower Missouri and middle Mississippi valleys the rainfall for the late spring and early summer is greater than in any other agricultural section of the country.

Topographic influence.—In the case of topographic influence, few important exceptions can be cited to the general rule that in mountainous regions precipitation increases with elevation, although this increase is by no means uniform in different localities, nor does it always continue to the highest elevations. Mountain masses exert a marked influence on precipitation, not only over the mountains themselves, but often over large areas to the leeward. From the Rocky Mountains westward the distribution of precipitation is largely determined by topographic conditions. The surface of this region is characterized by successions of mountain chains, either in massive ranges or more or less detached, with intervening narrow valleys, usually trending north and south. This condition of land relief results in large variations in the amounts of precipitation, even in near-by localities. The most notable example of this influence is found in the Sierra Nevada and Cascade ranges, which present a nearly unbroken massive ridge through California, Oregon, and Washington, lying almost at right angles to the path of the prevailing moisture-laden winds that blow from the ocean with no interruption except by the low Coast Range.

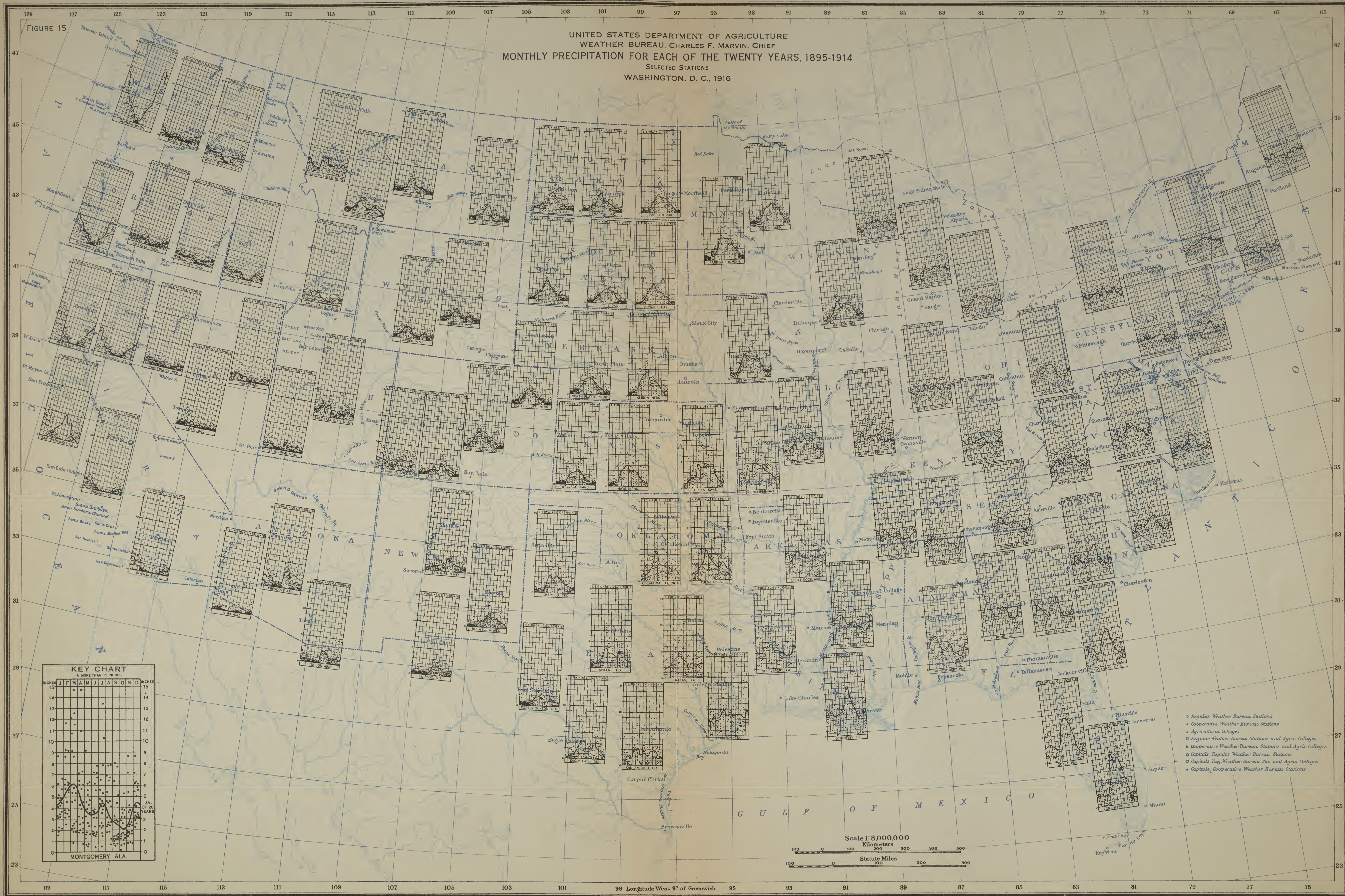


Figure 15.—These graphs show for selected stations the precipitation for each of the 12 months for each of the 20 years from 1895 to 1914, inclusive. The amount of precipitation for each month is shown by a dot, and the average monthly amounts are shown by the heavy lines. The graphs show the seasonal distribution of precipitation and also the variations from the average monthly precipitation that may be expected to occur in different sections of the country. These variations are large along the Pacific Coast. East of the Rocky Mountains they are largest, as a rule, in regions having the greatest average amounts of precipitation. From the Great Lakes region eastward the variations are comparatively small.

While investigations made for these mountains indicate that the zone of maximum precipitation probably lies at altitudes ranging from 4,000 to 6,000 feet, the increase in precipitation with altitude is far from uniform in more irregular mountain masses, especially those farther removed from ocean influences and with intervening mountain barriers. Therefore, it is not safe to assume that the relations found to exist in the Sierra Nevada hold good for the Rocky Mountain system. In fact, the meager information at hand indicates that the zones of maximum annual precipitation are usually found at considerably higher levels in the Rockies than in the Sierra Nevada. In portions of the Appalachians this topographic influence is likewise markedly shown. At several stations in the southern portion of these mountains, and also on Mount Washington, N. H., a precipitation of more than 80 inches occurs annually on the average, or nearly twice as much as at near-by lower elevations.

The influence on precipitation of successive mountain ranges and valleys disposed at right angles to the prevailing wind direction is markedly shown by conditions in the States of Washington and Idaho. Here on the windward side of the Olympic range in Washington the average annual precipitation is more than 100 inches. Immediately behind this belt of heavy rainfall lies the Puget Sound Basin, where the annual averages range generally from 20 to 50 inches. Next in succession come the more massive Cascades, with annual averages reaching more than 80 inches on the windward side, and these in turn are followed by the Columbia Plateau, where less than 10 inches are recorded at the lower elevations. To the east the precipitation increases with increasing elevation, until in the mountains of northern Idaho more than 40 inches are usually received.

Cyclonic influence.—In general, regions situated near the more frequented cyclonic paths receive greater amounts of precipitation than those more remote, but for the United States, at least, there are some important exceptions to this rule. The effect of such situation on the amount of precipitation is seen to some extent in the northern Rocky Mountain region, as compared with the localities to the southward, where cyclonic storms are less frequent and precipitation lighter, and, in combination with other favorable conditions, this factor accounts for the heavy rainfall on the North Pacific Coast. East of the Rocky Mountains, however, modifying influences are such that the areas of heaviest precipitation are considerably removed from the most frequented paths of cyclonic storms. Cyclonic storms frequently cross the northern Plains and Lake States, but the average annual amount of precipitation in these northern localities, 25 to 35 inches, is less than in the regions lying to the south, precipitation increasing in amount from the northern tier of States to the Gulf of Mexico, where the rainfall is about 60 inches. Likewise, the Northeastern States come under the direct influence of these storms more frequently than any other section of the country, yet precipitation here is only moderate in amount, notwithstanding the fact that the disturbances produce moist onshore winds.

Convectional currents.—Local convectional circulation of the atmosphere due to surface heating, also plays an important part in the production of precipitation, especially during the summer season, when much of the rainfall is the result of thunderstorms. These disturbances, known as heat thunderstorms, occur with greater frequency in the Gulf States than in any other portion of the country, which fact accounts in part for the comparatively heavy rainfall in that region.

PRECIPITATION TYPES.—As a result of the foregoing and other factors, not only the annual amount but also the seasonal distribution of precipitation varies greatly in different parts of the United States. Henry has recognized 11 more or less distinct types of seasonal distribution of precipitation, namely, Pacific, Sub-Pacific, Arizona, Mountain, Eastern Foothills, Plains, Gulf, Southern Appalachian and Tennessee, South Atlantic, Middle Atlantic and New England, and Lake Region and Ohio Valley. With respect to their agricultural significance and areas covered, several of these types may be combined, in this brief discussion, so there will remain six principal groups, broadly designated Pacific, Sub-Pacific, Arizona, Plains, Eastern, and Florida types. The Eastern type includes the originally forested eastern section of the United States, excepting the Florida Peninsula where the seasonal distribution of rainfall is so distinct as to become a separate type; the Plains type includes the prairie and plains regions and extends westward to the crest of the Rocky Mountains; the Arizona type includes western Texas, New Mexico, and Arizona; the Sub-Pacific type occupies the central and northern portions of the Plateau region between the Rocky Mountains and the Sierra Nevada and Cascade ranges; and the Pacific type extends from these ranges westward to the Pacific Ocean.

In this connection it is of interest to inquire whether the relative monthly distributions of precipitation, as indicated by the percentage graphs (fig. 13), are permanent, or whether at least some of the less distinctive types shown for the 20-year period in question might be materially altered by the adoption of a different series of years. Figure 14 shows for Marietta, Ohio, Manhattan, Kans., and Sacramento, Cal., representative stations of the Eastern, Plains, and Pacific types of precipitation, respectively, the variations for three consecutive 20-year periods, 1855 to 1874, 1875 to 1894, and 1895 to 1914. The variations for each month as shown for these types are about in proportion to the respective fluctuations occurring from year to year in the individual monthly amounts. That is, the Eastern and Plains types are more constant in relative monthly distribution than is the Pacific type, but in each case the distinguishing characteristics are maintained in each of the three periods. However, these graphs indicate that caution should be exercised in pointing out the less distinctive types from data based on a period as short as 20 years. For example, in the case of Marietta, the first period, 1855 to 1874, indicates that the rainfall for May is greater than for June, but the two later periods do not show this; while at Manhattan, the first period indicates the occurrence of more rain in June than in May, but this is not the case in the other two periods. In the case of Sacramento, the irregularity in the percentages for individual months shows that the amounts of precipitation received in that locality are extremely irregular, with great variations from year to year in the monthly totals.

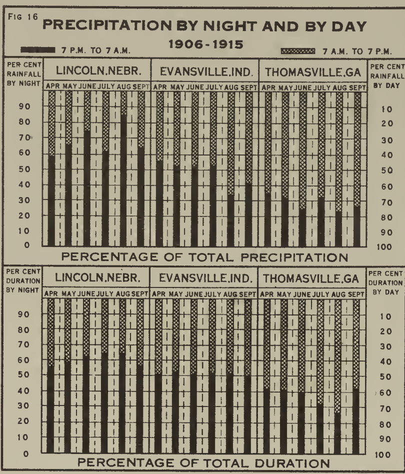


Figure 16.—Percentage of the total rainfall and duration of rain occurring at night (7 p. m. to 7 a. m. local standard time) and during the day (7 a. m. to 7 p. m.), for the months and at the stations indicated, for the 10-year period 1906–1915. Heavily shaded portions indicate nocturnal percentages. In the western portion of the Corn Belt about two-thirds of the precipitation during the warm season occurs at night, and in the east central portion of the Belt about one-half occurs during these hours. In the eastern portion of the Cotton Belt, on the other hand, only a little more than one-third of the warm season rainfall occurs during the night.

Pacific type.—This type is found in the Pacific Coast States from the Sierra Nevada and Cascade ranges westward to the Pacific Ocean. Its characteristic features are a marked winter concentration of precipitation and a summer dryness. In the western portions of Washington and Oregon from 40 to 50 per cent of the annual precipitation occurs during the winter months, December to February, the percentages increasing from north to south, amounting in California to 50 or 60 per cent (see fig. 13).

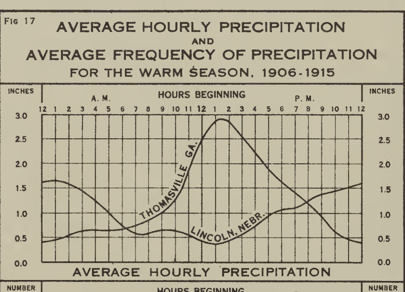


Figure 17.—The average hourly amount and frequency of precipitation for the warm season, April–September, for the 10-year period 1906–1915, at Lincoln, Nebr., and Thomasville, Ga. The nocturnal rainfall is comparatively heavy in the Corn Belt, the maximum occurring soon after midnight, whereas the heaviest rains in the Cotton Belt occur during the daytime, most frequently in the early afternoon. The values shown are the average hourly amounts received during the entire 6-months period.

The total precipitation for the winter (see fig. 20) on the windward sides of the Sierra Nevada and Cascade Mountains, as well as in the more or less detached members of the Coast Range north of the fortieth parallel, is, on the average, between 30 and 40 inches or more, while on the western side of the Olympic Mountains near the coast in Washington there is an area with more than 50 inches. The amounts occurring in the valleys increase from south to north. In the southern portion of the Great Valley of California the average amounts are less than 4 inches for the three winter months, but they increase to between 14 and 20 inches at the northern end of the valley. In the Willamette Valley and Puget Sound region the winter precipitation averages between 15 and 20 inches.

For the spring months, March to May (see fig. 30), the Pacific type of precipitation averages about one-half as much as for the winter, except that in the Cascade Mountains it is about two-thirds as great. In California the summer (see fig. 40) is practically rainless, except for an occasional shower in the mountains, and the rainfall is light to the northward, except that comparatively heavy rains occasionally continue into June (fig. 38). The proportion of the annual amount received during the summer months ranges from about 1 per cent in most of California to about 10 per cent in the vicinity of Puget Sound.

The rainy season sets in over the northern portion of the Pacific coast earlier than over the southern, the rainfall by November (fig. 53) becoming heavy in portions of Oregon and Washington, this being, in fact, the month of maximum rainfall in those localities. The precipitation for the fall months (see fig. 50) in the Pacific coast region ranges from 30 per cent of the annual amount in the northern portion to about 15 per cent in the southern.

Sub-Pacific type.—The designation "Sub-Pacific" has been given to the type of precipitation occurring in the eastern portions of Washington and Oregon and in Idaho, Nevada, and Utah. The seasonal distribution of precipitation over this region is distinguished from the Pacific type by the absence of a marked winter concentration, the precipitation for the spring months, except in the higher northern mountains of this region, being about the same as that occurring during the winter months. In the Columbia River Valley it is somewhat less, but in much of Nevada and Utah more rain falls during the spring months than in any other season. In the Sub-Pacific, as in the Pacific type, the rainfall during the summer months is very light and over considerable areas negligible. For the fall months it is about the same as for spring in eastern Washington and Oregon and in Utah, but somewhat less to the southward. Generally speaking, the Sub-Pacific type may be considered as one of fairly uniform distribution of precipitation for all months except the summer season.

The Sub-Pacific is a transitional type between the Pacific type and that found in the northern Rocky Mountains and Eastern Foothills, which culminates farther east in the Plains type. The relation between these rainfall types can best be seen from the inset charts of percentages of annual precipitation in each season, figures 21, 31, 41, and 51. On the chart of winter precipitation the area showing the highest percentages of the annual appears along the Pacific coast; on the spring chart this area appears in the northern Rocky Mountain and Eastern Foothill regions, but high percentages extend westward to Idaho and Nevada and eastward well into the Plains; while in summer the area has shifted still farther east and occupies the Plains proper. Thus as the season advances the area of relatively heavy precipitation occupies successive localities from the Pacific coast to the Great Plains.

The influences which control the occurrence of precipitation in the Sub-Pacific region are much the same as those which prevail west of the Sierra Nevada and Cascade ranges. The actual amount, however, is scanty during all seasons of the year, except at the higher elevations in the more northern States, and agricultural operations depend largely on irrigation or dry-farming methods.

Arizona type.—This type of rainfall prevails in extreme western Texas, New Mexico, Arizona, and in portions of southern Utah and Nevada, although it is not so well marked in these latter localities. It is characterized by relatively heavy rainfall during the months of July and August, when about 35 per cent of the annual precipitation occurs. April, May, and June are generally the months of least rainfall, and during the other months the distribution is quite uniform.

Summer rains in these districts are largely thundershowers occurring during the warmer portion of the day, caused mostly by convective circulation of the atmosphere. The amount and distribution of the winter rains depend largely on the frequency and position in latitude of cyclonic disturbances entering the United States from the Pacific.

Plains type.—This is a very important type agriculturally, covering as it does much of the great interior wheat and corn belts. It may be considered as including all the States from the Rocky Mountains eastward to the Great Lakes and the middle Mississippi River regions and thence southward to Missouri and Oklahoma. It is characterized by generous rains in the late spring and summer months and very light late fall and winter precipitation. It differs from the Arizona type in that the heavier rains begin earlier and end later, thus covering a longer period of the year, and also that precipitation occurs more frequently at night than in the afternoon (see fig. 9).

In portions of Montana and over small areas in the Dakotas and eastern Colorado the total precipitation for the three winter months averages less than 1 inch, while over the remaining area between the Rocky Mountains and a line extending from the Panhandle of

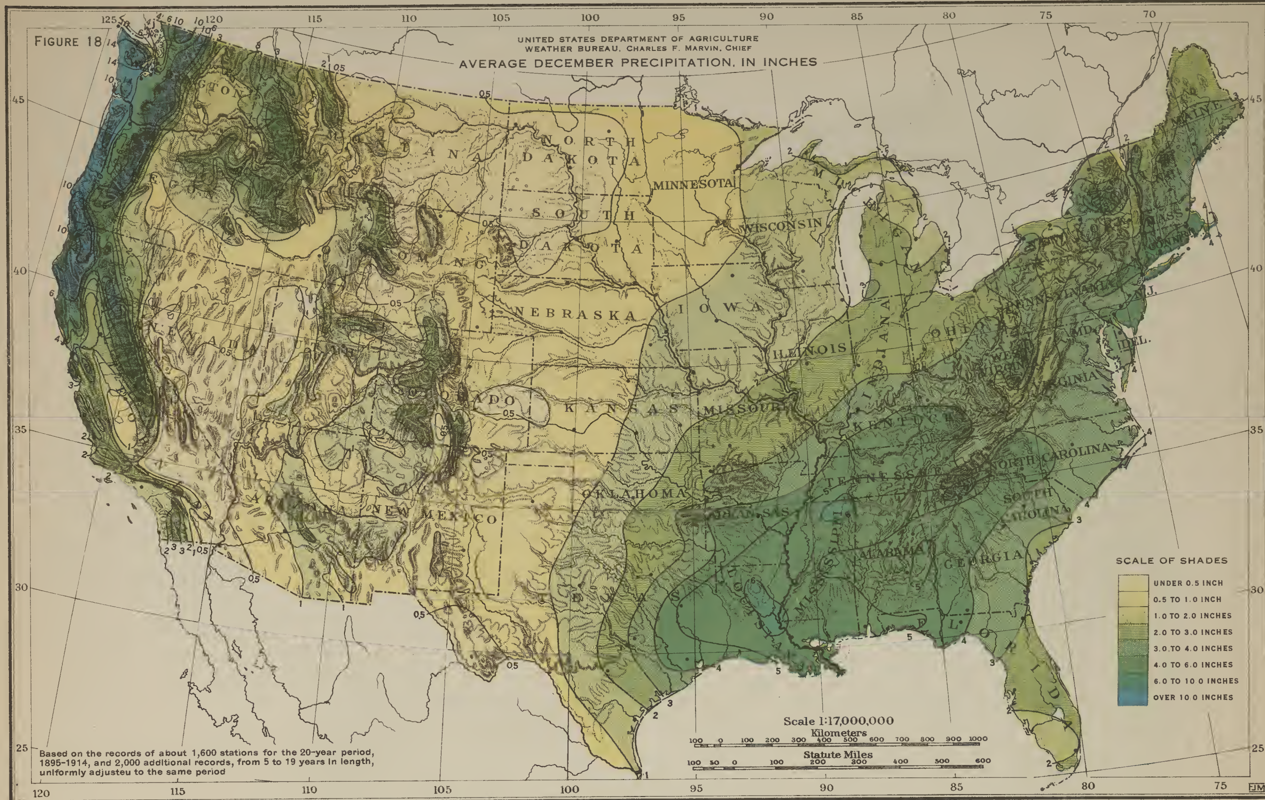


Figure 18.—By December in the Pacific Coast States the rainy season is usually well established, the central and northern portions of this region receiving more December precipitation than any other section of the country, and heavy snows have set in over the more elevated mountain districts. On the windward side of the Sierra Nevada, Cascade, and Coast ranges the monthly averages range from 10 to 14 inches or more or precipitation, and snow frequently accumulates to great depths. At the lower altitudes of the Interior Plateau and Rocky Mountain regions, and also over the Great Plains region, but little precipitation occurs during the month of December, large areas receiving usually less than 0.5 inch; but in the more elevated middle and northern Rocky Mountain districts from 2 to 4 inches or more occur on the average, almost wholly in the form of snow. In the eastern originally forested region the average December precipitation increases from about 2 inches along the northern border to 5 and 6 inches in the lower Mississippi Valley, but over the extreme Southeast there is a sharp diminution to less than 2 inches in portions of the Florida Peninsula.

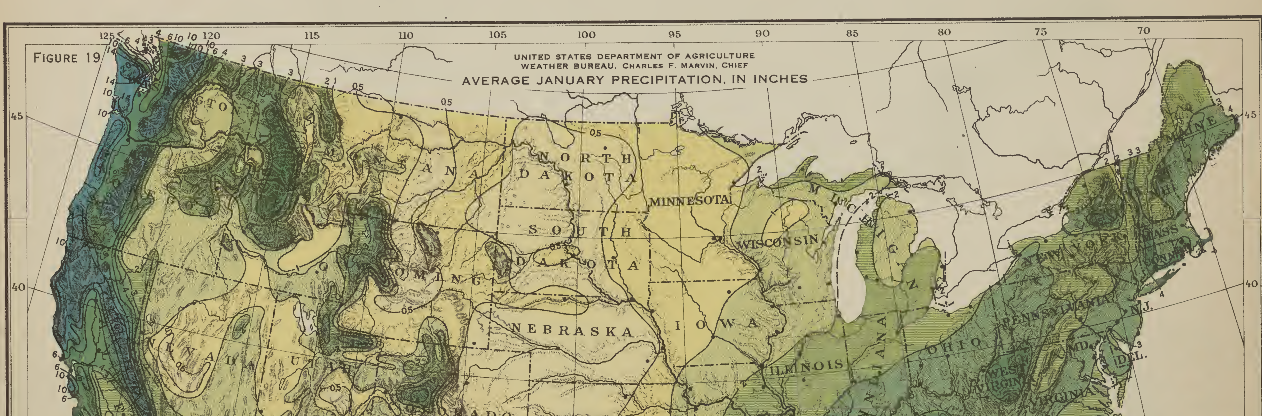


Figure 19.—In January the heaviest monthly precipitation in the United States occurs, as a rule, in the Pacific Coast region on the windward sides of the Coast Range, Sierra Nevada, and Cascade Mountains, where the monthly averages range from 10 to about 20 inches. To the eastward of the Sierra Nevada and Cascade ranges the precipitation is light, large areas receiving less than 1 inch. At the higher altitudes of the central and northern portions of the Rockies 4 inches or more occur, practically all in the form of snow. Large portions of the Plains region receive, on the average, less than 0.5 inch during the month, but to the southeastward there is a progressive increase to about 5 inches in portions of the lower Mississippi Valley and in the southern Appalachian Mountains. East of the Appalachians the amounts are smaller, considerable areas receiving, on the average, less than 3 inches.

FIGURE 20

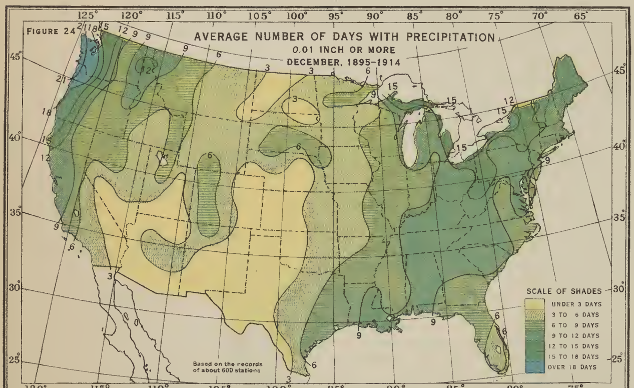
FIGURE 21

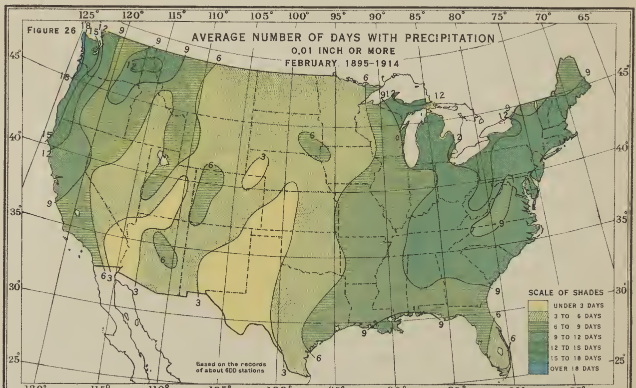
FIGURE 22

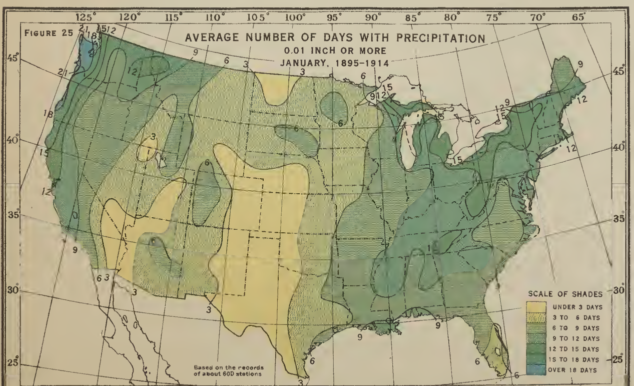
Figure 20.—This chart shows the average winter precipitation, December to February, inclusive. On the Pacific Coast winter is the wet season, precipitation from San Francisco northward being heavier than in any other portion of the United States. Maxima of 40 inches or more winter precipitation occur locally in the Sierra Nevada Mountains and along the Oregon and Washington coast. In the higher altitudes of the Rockies from 8 to 16 inches of precipitation occur during the winter season, wholly in the form of snow. In the Great Plains region the winter season is very dry, less than 2 inches occurring, as a rule, over most of the area. East of the Great Plains the winter precipitation gradually increases to a maximum of about 16 inches in southern Mississippi, in the higher altitudes of the southern Appalachians, and in the Adirondacks.

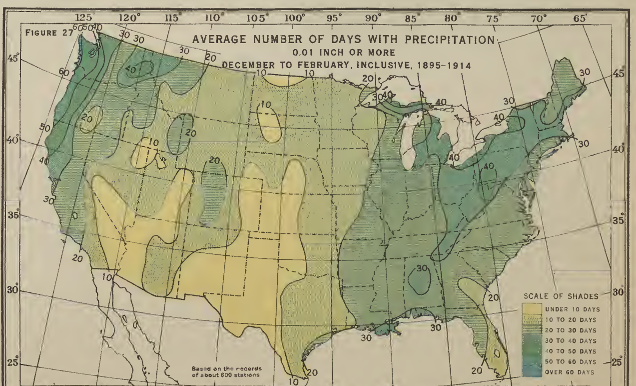
Figures 21 and 22.—The seasonal distribution of the annual precipitation varies widely in different sections of the United States. The inset chart in the lower left-hand corner shows the percentage of the annual precipitation that occurs during the winter months. In much of the Great Plains region the winter precipitation is small, generally less than 10 per cent of the annual, but in California the average winter precipitation is about half the average annual amount. The graph at the bottom to the right shows for a number of representative stations, well distributed over the country, the total winter precipitation that occurred in each of the 20 years whose record was used in preparing the large chart. It indicates the characteristics of distribution and variations from year to year in different localities.

Figure 23.—The geographic distribution of precipitation in February does not differ materially from that in January, except that the amounts are usually somewhat smaller in the northern portions of the Pacific Coast States and markedly smaller in the central and southern portions. Likewise, precipitation is usually lighter for this month in the central and northern Rocky Mountain districts, but over the Plains region in February somewhat larger amounts occur than in January. However, precipitation continues light in this region, large areas receiving, on the average, less than 0.5 inch. In the central Gulf States and the southern Appalachian Mountain region precipitation in February is comparatively heavy, generally 5 to 6 inches or more, but in the Florida Peninsula the average amounts are small, ranging from 2 to slightly more than 3 inches.









Figures 24, 25, and 26 show the average number of days with precipitation (0.01 inch or more) for the months of December, January, and February, respectively, and Figure 27 shows the total number of days for the winter season. Along the North Pacific Coast during the months of December and January rain occurs, on the average, on about two-thirds of the days, and February has only slightly fewer rainy days. East of the Rocky Mountains the number of rainy days increases from about 3 for each month in the western portion of the Great Plains region to from 9 to 15 in most sections east of the Mississippi River. There is, however, a sharp falling off in the extreme southeast to less than 6 days each month in portions of the Florida Peninsula.

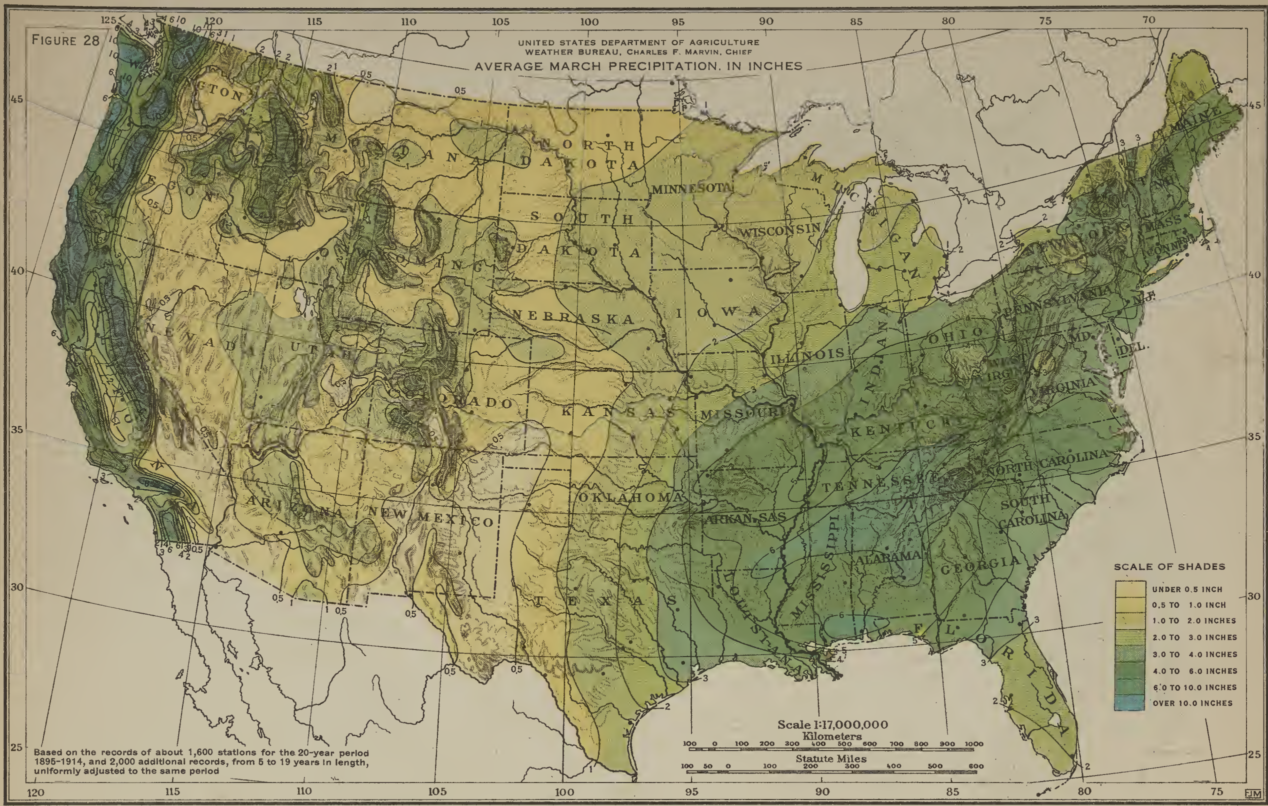


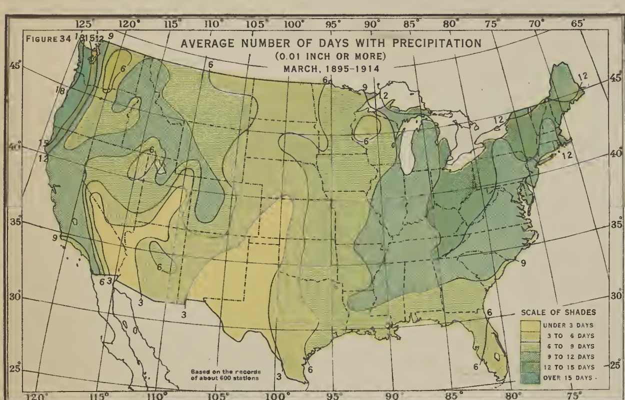
Figure 28.—At the higher altitudes of the Pacific Coast States precipitation continues heavy in March, with much snow in the mountains; in fact, at some places March is usually the month of heaviest snowfall. The average snowfall during March at Summit, Cal., is about 7 feet. Over the Interior Plateau region and at the higher altitudes in the Rockies the precipitation for March is usually about the same as that during the preceding month, but in the Great Plains region there is a rather marked increase, the March average ranging generally from 1 to 2 inches. In the States east of the Great Plains the averages range from 2 to 3 inches along the Canadian border to 6 inches or more over large areas from Tennessee southward, but over the Florida Peninsula usually less than 3 inches occur.

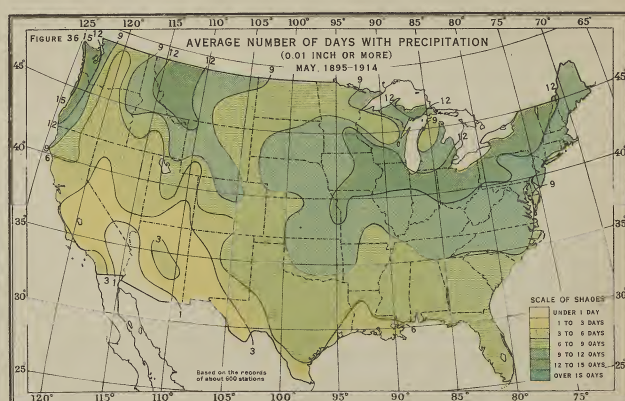
Figure 29.—West of the Continental Divide there is usually a marked decrease in the amount of precipitation received during April, except in the Central and Northern Plateau region, and, as a rule, much less snow occurs at the higher altitudes. The increase in precipitation in the eastern foothills of the Rocky Mountains and throughout the Plains States becomes pronounced during April, the monthly averages in some sections increasing to about 2.5 inches, as compared with less than 0.5 inch for a winter month. In most districts east of the prairie region, however, the April rainfall is usually less than for the preceding month, the averages in only comparatively small areas in the lower Mississippi Valley reaching as much as 5 inches. In the Florida Peninsula the rainfall continues scanty, averaging only about 2 inches.

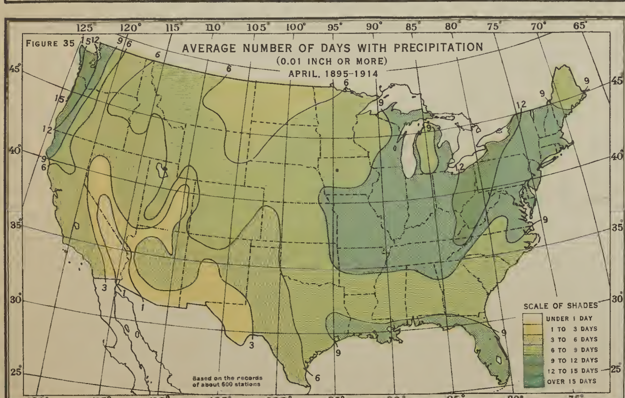
Figure 30.—This chart shows the average spring precipitation, March to May, inclusive. In the Pacific Coast States there is a marked diminution in the amount of precipitation during the spring months, except in the eastern portions of Washington and Oregon. There is also much less snowfall in the Rocky Mountain region. Over the Great Plains region precipitation increases rapidly with the advent and advance of spring, the total for the three spring months being much larger than for the winter. East of Lake Michigan and the Mississippi River there is in most districts no noteworthy difference in the amount of precipitation received during the spring months and that received in the winter season.

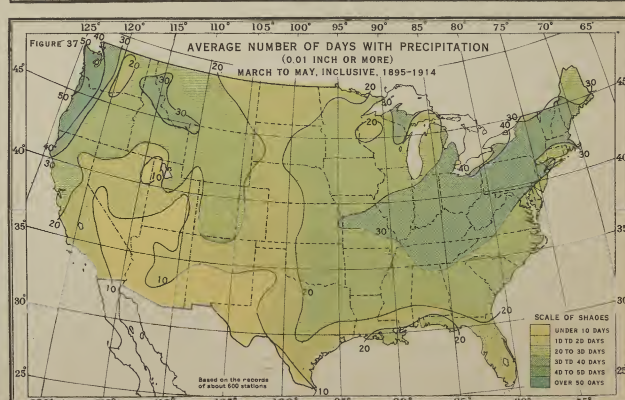
Figures 31 and 32.—The inset chart in the lower left-hand corner shows the percentage of the annual precipitation that occurs during the spring months. The proportion is largest in the western portions of Nebraska and South Dakota and in the adjacent Rocky Mountain States, where from 30 to 35 per cent, or more, of the annual precipitation is received during the spring. The graph at the bottom to the right shows for a number of representative stations, well distributed over the country, the total spring precipitation that occurred in each of the 20 years whose record was used in preparing the large chart. It indicates the characteristics of distribution and variations from year to year in different localities.

Figure 33.—West of the Sierra Nevada and Cascade ranges in the Pacific Coast States precipitation continues to diminish during the month of May, but throughout the central and northern portions of the Interior Plateau and Rocky Mountain regions and on the Great Plains there is a rather marked increase over the preceding month. The outstanding feature of the geographic distribution of precipitation for May is the comparatively large amount received in the central and eastern portions of Kansas and Oklahoma and the western portions of Arkansas and Missouri, where the rainfall during this month averages 5 to 6 inches, or more, and is larger than in any other agricultural section of the country. This is also the region of greatest thunderstorm activity for the month, the average number of days on which thunderstorms occur being about 8. Throughout the regions east of the Mississippi River the average precipitation in May is much more uniform than in the preceding months, ranging generally from about 3 to slightly more than 4 inches.









Figures 34, 35, and 36 show the average number of days with precipitation (0.01 inch or more) for the months of March, April, and May, respectively, and Figure 37 shows the total number for the spring season. Along the North Pacific Coast rainfall is less frequent during the spring months than during the winter, precipitation occurring, as a rule, on about one-half the days. In the Plains region there is a marked increase in rainfall frequency with the advent of spring, rain occurring, on the average, from 6 to 9 days each month during March and April, with somewhat greater frequency during May. East of the Mississippi River the number of rainy days for the spring season as a whole ranges from about 20 along the Gulf Coast to about 40 in portions of the Great Lakes region.

Figure 38.—The most noteworthy feature of the geographic distribution of the June rainfall is the relatively large amount received between the eastern foothills of the Rocky Mountains and the Mississippi River as compared with the annual amount in that region. In most of this area the June rainfall ranges from 3 to 5 inches, being 15 to 20 per cent of the annual amount. East of the Mississippi River the rainfall for the month ranges from about 3 inches along the Canadian border to from 6 to 8 inches near the Gulf Coast. The heaviest rainfall for June usually occurs in the Florida Peninsula, in portions of which more than 8 inches are received on the average, which is in marked contrast to the several preceding months with comparatively little rainfall. From the Rocky Mountains westward precipitation for June is usually scanty, except that 3 to 4 inches, or more, occur, on the average, at the higher altitudes in the northern districts. In the central and southern sections of the Pacific Coast States the dry season is on and the rainfall is negligible in amount, except for occasional showers in the mountains.

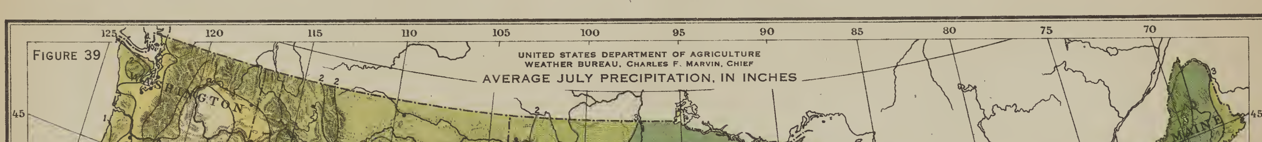
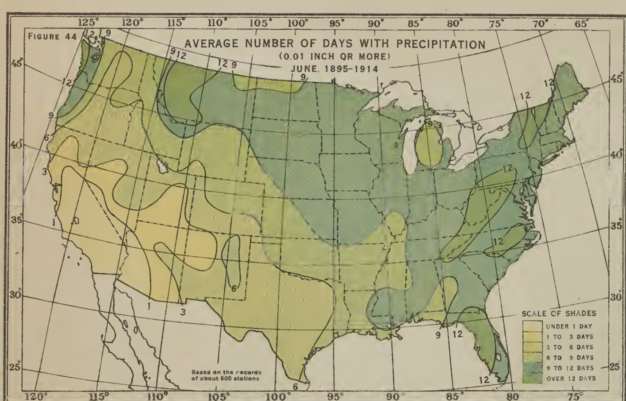


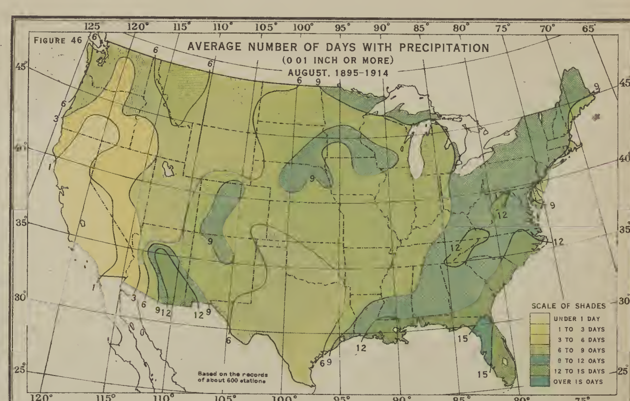
Figure 39.—July rainfall results largely from local thunderstorms, which are more numerous in this than in any other month. The region of the greatest activity is found along the west coast of the Florida Peninsula, where thunderstorms usually occur on more than 20 days of the month, and here the average rainfall for the month ranges from 8 to 10 inches, or more, being heavier than in any other section of the country. Over much of the Great Plains the average July rainfall is appreciably less than for June, but to the eastward there is in general an increase in amount over the preceding month. In the southwestern region, including western Texas, New Mexico, and most of Arizona, July is usually the wettest month of the year, but in the Pacific Coast States the dry season is at its height. No rain is expected in California, except for an occasional local shower in the mountains, and farther north, in Washington and Oregon, but little rain occurs.

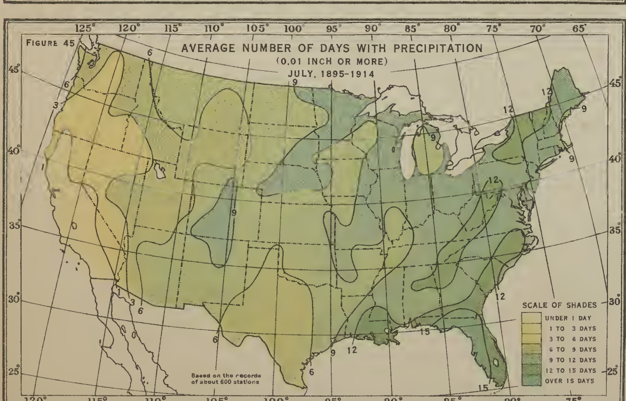
Figure 40.—This chart shows the average summer precipitation, June to August, inclusive. In the Pacific Coast States the summer is almost rainless, except in the more northern sections, where showers may be expected to occur occasionally, especially in the mountains. In the Plains States precipitation in the summer season continues comparatively heavy, and in New Mexico and eastern Arizona much of the annual precipitation occurs during the summer months, mostly in July and August. Along the Central and East Gulf and South Atlantic coasts rainfall is heavy during this season, the totals for the three months ranging from 16 to 25 inches, and it is comparatively heavy also in portions of the Appalachian Mountain region, where locally the summer totals reach as much as 20 inches.

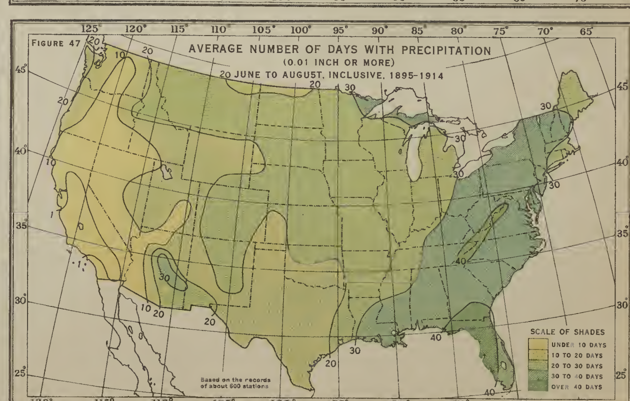
Figures 41 and 42.—The inset chart in the lower left-hand corner shows the percentage of the annual precipitation that occurs during the summer months. In the central and northern Plains States from 45 to 50 per cent of the annual precipitation occurs during this season of the year, but in the Pacific Coast States little rain occurs during the summer months, much of California receiving, on the average, less than 1 per cent of the annual amount. The graph to the right shows for a number of representative stations, well distributed over the country, the total summer precipitation that occurred in each of the 20 years whose record was used in preparing the map. It indicates the characteristics of distribution and variations from year to year in different localities.

Figure 43.—In August, as in July, rainfall is largely the result of thunderstorms, and the region of their greatest frequency, as well as that of heaviest precipitation, is found in portions of the Southeastern States, where the average rainfall for the month ranges from 6 to 10 inches. In general the geographic distribution of precipitation for August does not differ materially from that of July, although in portions of the Plains States the amounts are usually somewhat less in August. In most of New Mexico and Arizona the rainfall for August is comparatively heavy, this and the preceding month constituting the rainy season in that region. Elsewhere west of the Rocky Mountains the August rainfall, like that for July, is agriculturally unimportant.









Figures 44, 45, and 46 show the average number of days with precipitation for the months of June, July, and August, respectively, and Figure 47 shows the total number for the summer season. This is the dry season in the Pacific Coast States and rainfall is infrequent. Rain occurs on the average on less than one day during the entire season at the lower elevations in California, but the number of rainy days increases northward to about 20 for the season along the North Pacific Coast. East of the Rocky Mountains the number of rainy days for the three summer months increases from between 20 and 30 in most of the Plains region to about 40 in the central Appalachian Mountain region and in the extreme Southeast.

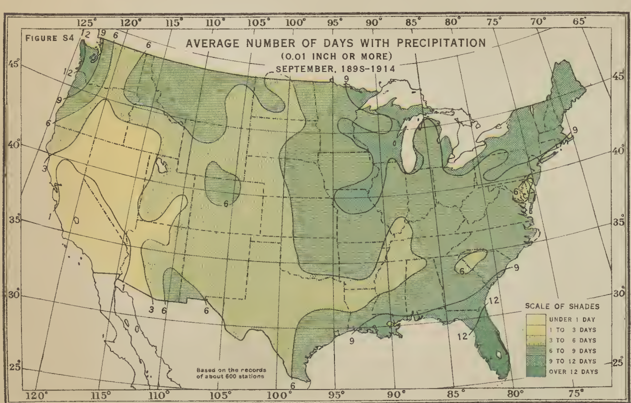
Figure 48.—With the advent of autumn the rainfall east of the Rocky Mountains in general becomes appreciably less, but in a few districts it is somewhat greater, notably in portions of the middle Mississippi and lower Missouri valleys, where the average September rainfall is slightly more than 4 inches, and along the southeastern coast of the Florida Peninsula, where it reaches 8 inches. The Florida Peninsula and the central and eastern Gulf coasts constitute the region of maximum September rainfall, receiving on the average from 6 to 8 inches; but the amounts decrease rapidly to the northward, where large areas usually receive less than 3 inches. In New Mexico and Arizona September rainfall is usually much less than that of August; but on the North Pacific Coast there is a marked increase, the averages ranging from 4 to 6 inches as compared with 1 to 2 inches for the preceding month.

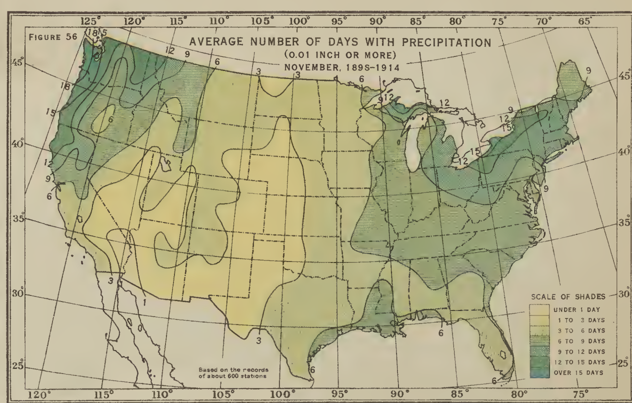
Figure 49.—East of the Rocky Mountains precipitation for October is usually considerably less than for the months immediately preceding. The decrease in precipitation in these central and eastern districts usually begins during the month of August, becomes more pronounced in September, and continues throughout October. The most noteworthy diminution from September to October occurs along the central and eastern Gulf coasts, where the October averages range from 3 to 4 inches, being only about one-half as large as in September. Likewise the falling off is rather pronounced in the middle and upper Mississippi and lower Missouri valleys, as well as over the Plains States. From the Rocky Mountains westward precipitation for October, as a rule, does not differ materially from that for September, except in the Pacific Coast region, where rains become more frequent with the advance of fall, especially in the northern portion, and at the higher altitudes. In these districts the October precipitation reaches 6 to 10 inches.

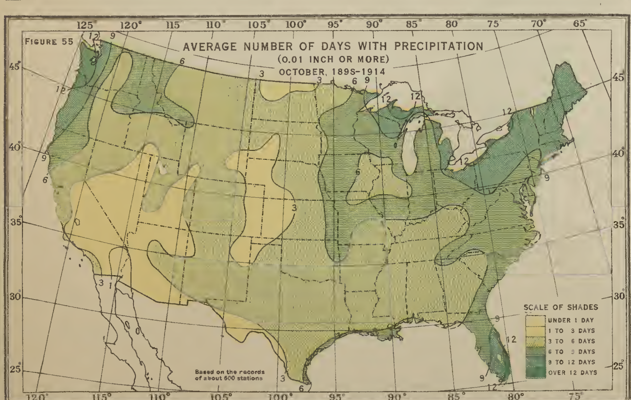
Figure 50.—This chart shows the average fall precipitation, September to November, inclusive. In the Pacific Coast States the rainy season sets in during the fall months and it is well established in the northern section by the end of November, when heavy snows usually begin at the higher altitudes. During November heavy snows often occur also in the mountains of Montana and Idaho. In the Great Plains region there is a rather rapid falling off in the amount of rainfall with the advent of autumn, and this condition is general also in most districts east of the Plains, but the diminution is not so marked. The heaviest precipitation during the fall season east of the Rocky Mountains occurs in the southeastern portion of the Florida Peninsula, where the totals for the three fall months at several stations are as much as 22 inches.

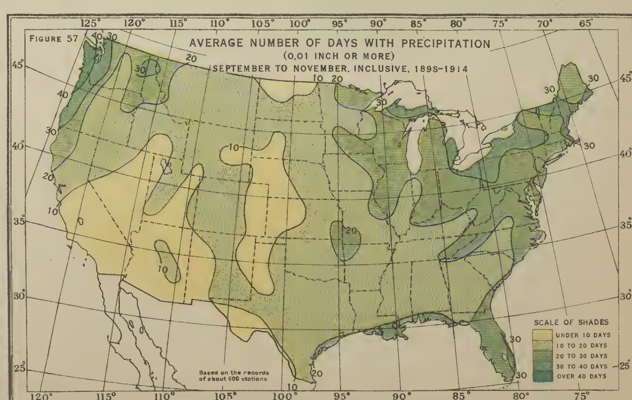
Figures 51 and 52.—The inset chart in the lower left-hand corner shows the percentage of the annual precipitation that occurs during the fall months. In most of the important agricultural districts of the country precipitation during the fall season is relatively light, usually ranging between 15 and 25 per cent of the annual amount. The graph at the bottom to the right shows for a number of representative stations, well distributed over the country, the total fall precipitation that occurred in each of the 20 years whose record was used in preparing the large chart. It indicates the characteristics of distribution and variations from year to year in different localities.

Figure 53.—In November thunderstorms are of much less frequent occurrence and the larger, or cyclonic, atmospheric disturbances are more active and become the principal source of precipitation. East of the Rocky Mountains the heaviest rainfall in this month usually occurs in the central and lower portions of the Mississippi Valley, where, at some places, the November rainfall averages slightly more than 4 inches; but from this region the average precipitation decreases in all directions. The decrease is especially marked to the westward and northwestward, the rainfall for the month in the Dakotas, Nebraska, and the central and western portion of Kansas being less than 1 inch. In the southeastern portion of the Florida Peninsula there is a remarkable decrease from averages of 8 to 10 inches in October to those of 2 to 3 inches in November. On the Pacific Coast the rainy season becomes more pronounced in November, the average rainfall for the month ranging from about 1 inch on the southern coast of California to from 14 to 20 inches on the coasts of Washington and Oregon. November is frequently the month of maximum precipitation along the North Pacific Coast.









Figures 54, 55, and 56 show the average number of days with precipitation for the months of September, October, and November, respectively, and Figure 57 shows the total number for the fall season. With the advent of fall, precipitation, as a rule, becomes of more frequent occurrence in the Pacific Coast States and less frequent east of the Rocky Mountains. By November the rainy season is well established along the Central and North Pacific Coast, precipitation occurring in the western portion of Washington and Oregon on about 18 days during this month, and along the northern California coast on from 10 to 15 days. East of the Mississippi River rain occurs, as a rule, with less frequency during the fall months than during any of the other seasons, the average number of days with rain during the three months in many of the important agricultural sections being less than 20.

Figure 58.—Deficiencies of considerable amount from the average precipitation during the warm season of the year are of special agricultural significance. This and the succeeding seven charts show for each month from March to October the relative frequency, expressed in percentage, and based on the 20-year period 1895–1914, that precipitation was less than half the average for the respective months. The localities having the least frequent occurrences of deficient precipitation of this amount for the month of March are found in the Middle Atlantic and portions of adjoining States, and also in the lower Mississippi Valley and along the North Pacific Coast, where in only 1 or 2 years of the 20 was the precipitation during March less than half the monthly average. The largest percentages for this month appear in Arizona, New Mexico, and the western portion of Texas, where over considerable areas the precipitation was less than 50 per cent of the average in half the years or more.

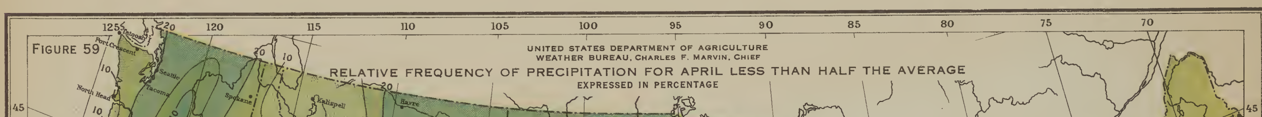


Figure 59.—This chart shows the relative frequency, expressed in percentage, and based on the 20-year period 1895–1914, that precipitation for the month of April was less than half the average. In the lower Missouri and middle Mississippi valleys, in Kentucky, and from the Virginias and Ohio northeastward deficiencies of this amount were, as a rule, infrequent for April during this period, only 1 to 2 years in the 20 having for this month less than 50 per cent of the average precipitation. On the other hand, in the regions lying just east of the Rocky Mountains, and also in portions of the eastern Gulf States, the percentages are large, there having been in those localities as many as 6 to 8 years of the 20 with deficiencies of this amount in the April precipitation. West of the Rocky Mountains the percentages are large, as a rule, the largest values appearing in the far Southwest, where at some places in more than half the years the precipitation for April was less than half the average.

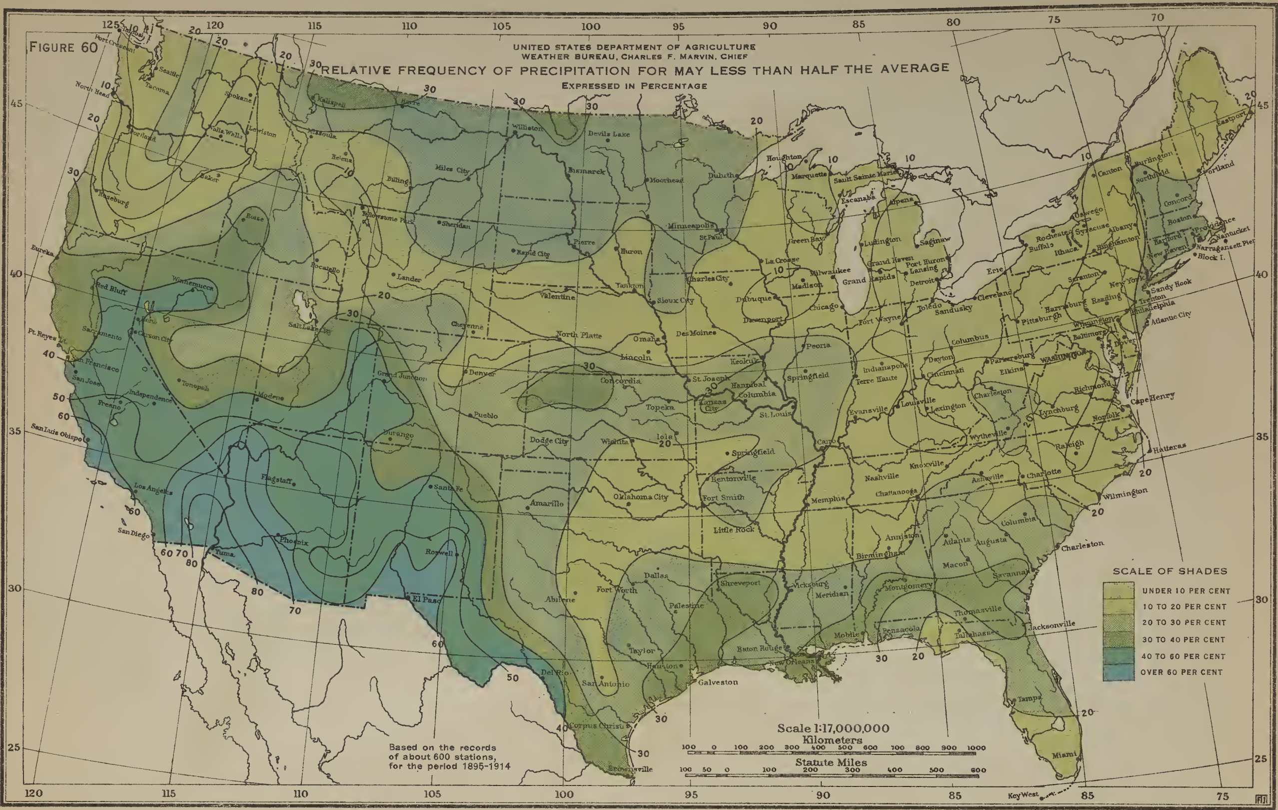


Figure 60.—This chart shows the relative frequency, expressed in percentage, and based on the 20-year period 1895–1914, that precipitation for the month of May was less than half the average. In general, the districts that had fewer such deficiencies for this month during the 20-year period are found in the States bordering on the Great Lakes, where in some localities only 1 year in the 20 had for May less than half the monthly average. Other areas of comparatively small percentages appear in the Middle Atlantic States and in parts of the Plains region. In portions of the lower Missouri Valley, where for April the percentages were as low as 5 to 10, May had deficiencies of this amount in 25 to 30 per cent of the years. The largest percentages appear in the far Southwest, where at some places as many as 16 years of the 20 had for this month less than half the average monthly rainfall. This is due to the fact that rainfall in those districts is usually very light, and occasional heavy rains unduly magnify the averages.

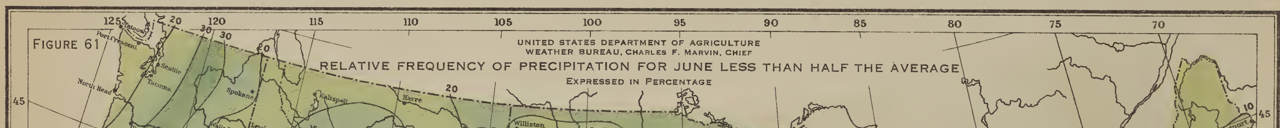


Figure 61.—This chart shows the relative frequency, expressed in percentage, and based on the 20-year period 1895–1914, that precipitation for the month of June was less than half the average. The areas of least frequent occurrence of deficiencies in precipitation of this amount for June are found in the Middle and South Atlantic States, the Ohio Valley and portions of the Great Lakes region, and also in portions of the spring-wheat belt, where, as a rule, only 1 or 2 years in the 20 had for this month less than half the average rainfall. In Texas, Arizona, and California, and generally to the westward of the Rocky Mountains the percentages are large, except along the North Pacific Coast and in the upper Columbia and Snake River valleys.

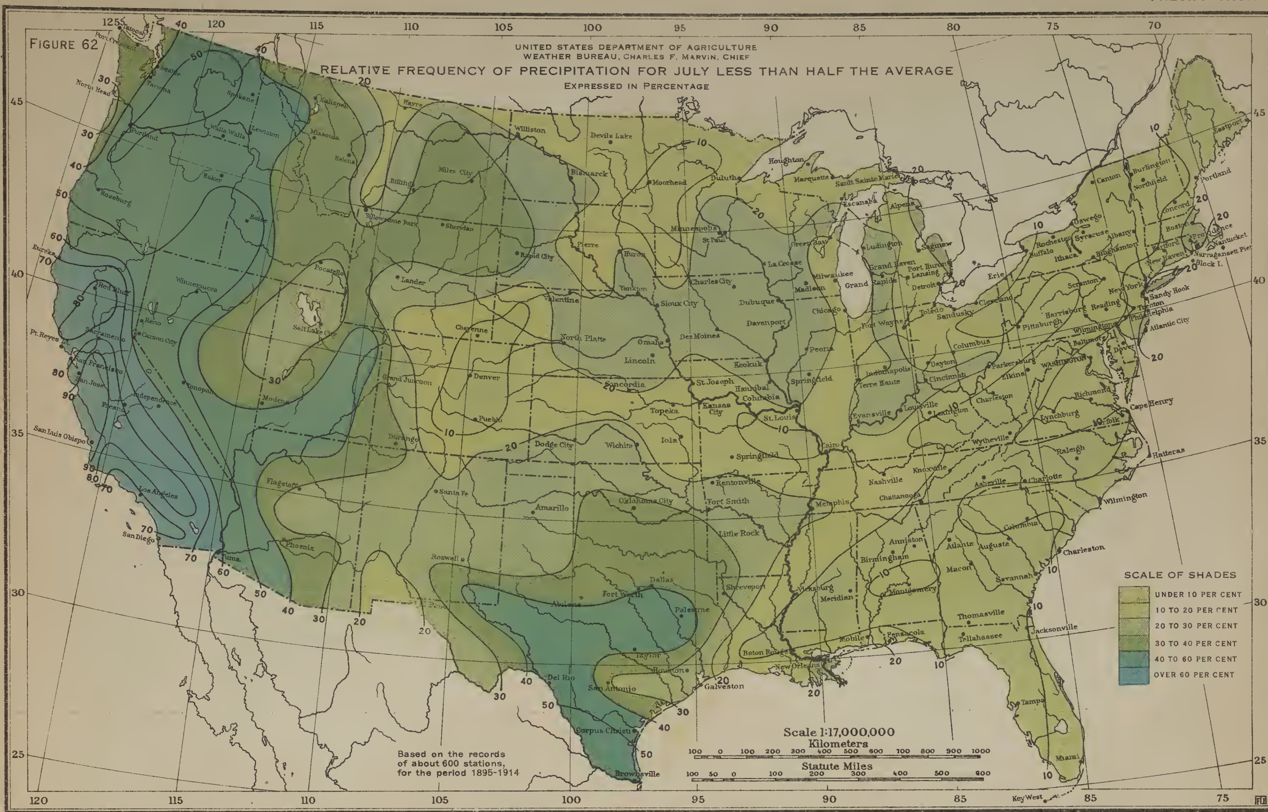


Figure 62.—This chart shows the relative frequency, expressed in percentage, and based on the 20-year period 1895-1914, that precipitation for the month of July was less than half the average. In the districts east of the Mississippi River July, as a rule, had few deficiencies of this amount, particularly in the central and eastern portions of the Cotton Belt, where in a number of localities only one such deficiency is recorded for the entire 20-year period, and at some points in no year was the July rainfall less than half the average. The largest percentages east of the Rocky Mountains appear in Texas, where in most places the July rainfall was less than half the average in about 8 of the 20 years. The percentages are large in the Pacific Coast States, particularly in California, but in Arizona and New Mexico they are much smaller than for June, due to the fact that in these States the rainy season is on and the average is not affected so greatly by occasional heavy rains as it is in other seasons of the year.

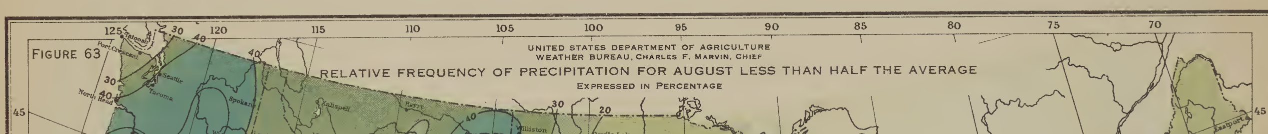


Figure 63.—This chart shows the relative frequency, expressed in percentage, and based on the 20-year period 1895-1914, that precipitation for the month of August was less than half the average. In most districts east of the Mississippi River fewer than 4 years of the 20 had during August less than half the average precipitation for this month. Other districts showing small percentages for August are found in north-central Arkansas, eastern Missouri, portions of the upper Mississippi and middle Missouri valleys, the central Rocky Mountain region, and in Arizona, the last named being due to the continuation of the rainy season in that region. Except in Arizona, the percentages in the districts west of the Rocky Mountains are large, less than half the average rainfall for the month occurring generally in from 8 to 16 years of the 20. In most of Texas deficiencies of this amount occurred in August in more than one-third of the years.

Figure 64.—This chart shows the relative frequency, expressed in percentage, and based on the 20-year period, 1895-1914 that precipitation for the month of September was less than half the average. East of the Mississippi River, except in portions of the Lake region and of South Atlantic States, deficiencies of this amount were of more frequent occurrence during September than during the preceding months of the warm season, many localities having as many as 5 years of the 20 with less than half the average monthly rainfall. West of the Mississippi River the smallest percentages for this month are found in eastern Kansas and central Missouri, where only 3 or 4 years of the 20 had rainfall in September, less than half the monthly average. In Texas and most districts west of the Rocky Mountains the September percentages are appreciably less than those for August, but in Arizona they are markedly greater, due to the cessation of the rainy season in that State.

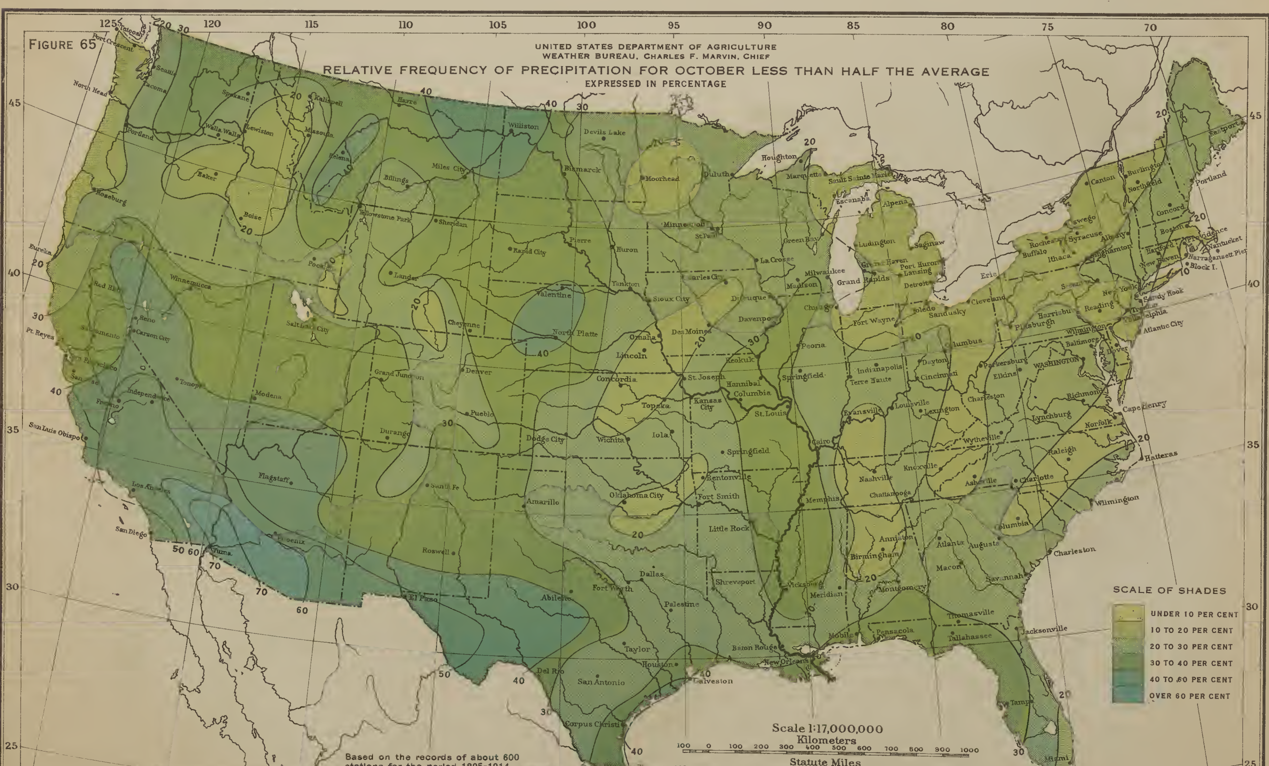


Figure 65.—This chart shows the relative frequency, expressed in percentage, and based on the 20-year period 1895-1914, that precipitation for the month of October was less than half the average. Along the Mississippi River and eastward the October percentages are rather large as compared with the other months included in this series of percentage charts, but in most of Texas and over the eastern portions of the Plains States they are comparatively small. Other areas of rather small percentages for this month are found along the North Pacific Coast and in the northern Interior Plateau region. The largest percentages appear in the far Southwest, particularly in the extreme southeastern portion of California and southwestern Arizona, where in 14 years of the 20 precipitation for October was less than half the average monthly amount. Comparatively large percentages appear also in Montana and the western portions of the Dakotas and Nebraska.

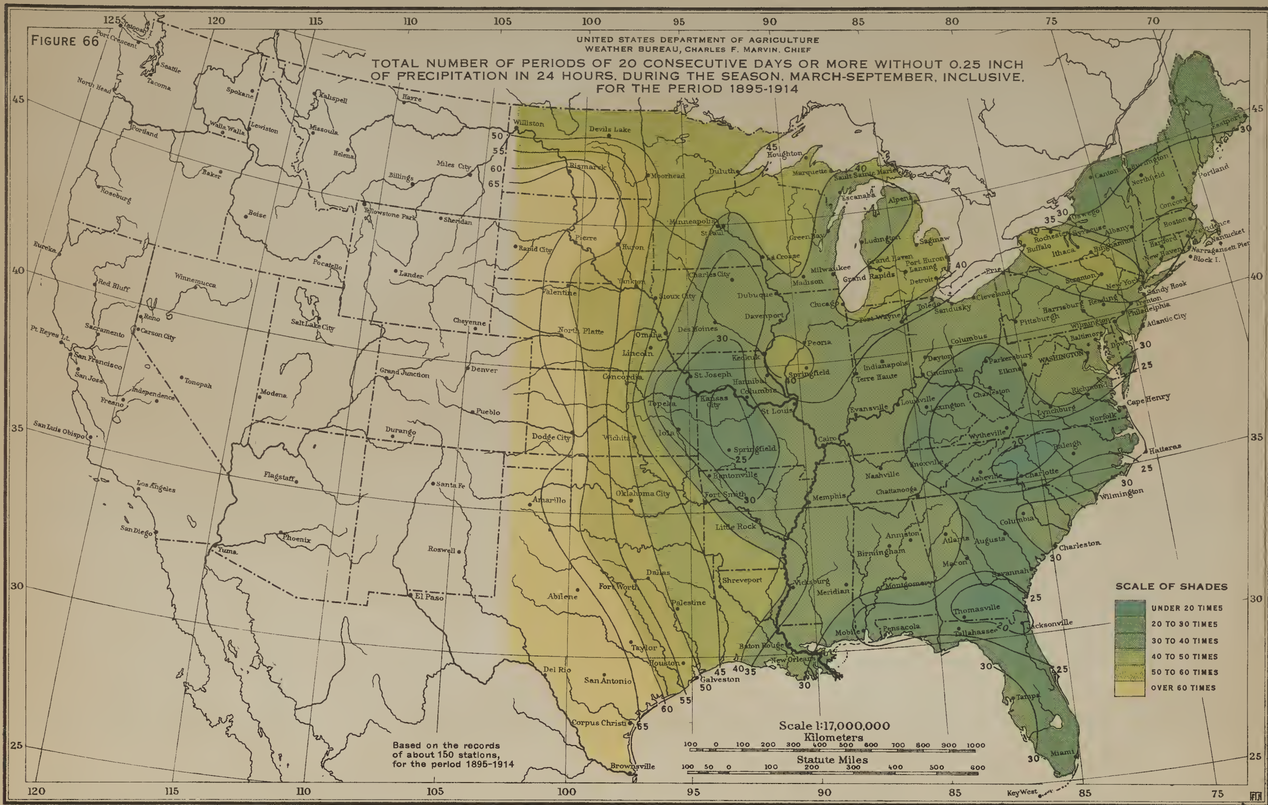


Figure 66.—This chart shows, for the season from March 1 to September 30, for districts from the Great Plains eastward, the total number of periods of 20 consecutive days, or more, without one-fourth inch of precipitation in 24 hours during the 20-year period 1895-1914. The chart is based on the records of all regular reporting stations within the districts mentioned having full 20-year records, about 150 in number. The areas having the fewest such periods of deficient precipitation are found in the Middle and South Atlantic States and in the lower Missouri Valley, where such droughts occurred on the average about once in a season. The most frequent occurrences are found in the western portions of the Plains States, where the average is about three in each season.

Texas northeastward through central Minnesota the winter precipitation is less than 2 inches.

With the advance of spring, however, the amount of precipitation in this region increases rapidly, although the increase is not pronounced until May. In Montana and the Dakotas, May and June are the months of heaviest rainfall, the amount being somewhat greater in June, while for the other States included in this type the rainfall in May, June, and July is about equal. It will be noted by reference to the monthly precipitation charts, figures 33, 38, and 39, that a large area immediately to the westward of the Mississippi River, including a half dozen or more States, either wholly or in part, receives on the average more than 4 inches of rainfall during each of the months of May, June, and July. The seasonal distribution of precipitation in percentages of the annual for much of the Plains region is about as follows: Winter, less than 10 per cent; spring, 25 to 30 per cent; summer, 40 to 50 per cent; fall, 15 to 20 per cent.

Eastern type.—This type, broadly speaking, includes all the country east of that covered by the Plains type, except the Florida Peninsula, and is characterized by comparatively uniform distribution of precipitation throughout the year, especially north of the Cotton Belt. However, the rainfall during the autumn months is, in general, lighter than for any other season, particularly in most of the Cotton Belt, a condition favorable for the gathering of the cotton crop. In the Southern States there are some interesting fluctuations in the amounts of rainfall from month to month, but no pronounced seasonal variations of great agricultural importance are shown.

Florida type.—Important seasonal variations in precipitation are found in the Florida Peninsula. Here the seven months from November to May, inclusive, are comparatively dry, only from 2 to 3 inches of rainfall occurring on the average in each month, but during the other five months precipitation is usually heavy, July and August being especially wet on the west coast, where more than 10 inches fall on the average in each month, while on the east coast similar amounts occur in September and October. During the five months June to October, inclusive, rainfall is usually heavier over the Florida Peninsula than in any other section of the country. Two distinct factors operate to produce this heavy rainfall, convectional thunderstorms being responsible for the large amount usually received along the west coast during July and August, while the heavy rainfall on the eastern side of the peninsula in September and October is due to the fact that this coast comes under the direct influence of the tropical storms that occasionally occur in that region.

The heavy late summer rainfall, characteristic of the Florida type, extends northward along the Atlantic and westward along the Gulf Coasts, gradually merging in each direction into the more uniform seasonal distribution of the Eastern type of precipitation.

Area of maximum rainfall by months.—The area of maximum rainfall east of the Rocky Mountains for the several months of the year usually shows average amounts of from 5 to somewhat more than 6 inches, except from June to September, inclusive, which have from 8 to more than 10 inches. Excluding the more or less isolated cases, the locations of this area for the several months are as follows: In January it occupies the lower Mississippi Valley; by February it is farther east and overlies the southern portions of Mississippi and Alabama; in March it includes the northern portions of those States, with extensions into northern Georgia, western North Carolina, and eastern Tennessee. In April it again appears in the lower Mississippi Valley, and in May it occupies western Arkansas and eastern Oklahoma. In June it appears in the Florida Peninsula, where it remains during the following four months. In November, the only time during the year with averages less than 5 inches, it occupies the Mississippi Valley from western Tennessee southward, while in December it is restricted to a limited area in northern Mississippi.

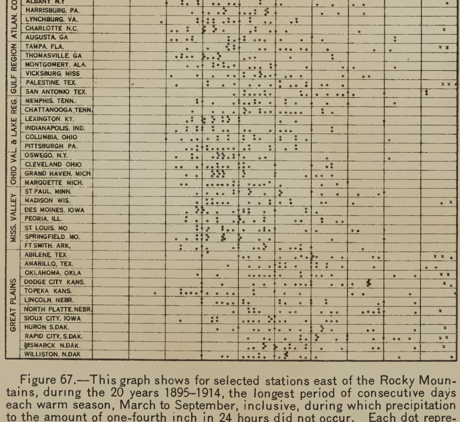


Figure 67.—This graph shows for selected stations east of the Rocky Mountains, during the 20 years 1895–1914, the longest period of consecutive days each warm season, March to September, inclusive, during which precipitation to the amount of one-fourth inch in 24 hours did not occur. Each dot represents the longest such period for a single season, there being 20 dots for each station. The stations are arranged by geographic divisions.

Rainfall of the crop-growing season.—Figure 8 shows for the different sections of the country the average amount of precipitation occurring during the warm season, April to September, inclusive, often designated the crop-growing season. In the eastern two-thirds of the United States it is the rainfall of this period with which the farmer is mostly concerned, but from the Rocky Mountains westward the amounts occurring in the winter months are of greatest importance. In fact, for some western localities the amount of snow stored in the mountains during the winter, as a reserve water supply for irrigation purposes in the following growing season, largely determines the degree of success for many farming operations. Again, in most of the Pacific Coast region fall-sown grains under the influence of comparatively mild temperatures and ample moisture conditions during the winter season grow steadily and mature after the cessation of rains, using the moisture stored in the soil during the wet winter months.

East of the Rocky Mountains these conditions are largely reversed. Here fall-sown grains make practically no advancement after winter sets in, but with the advent of spring growth is rapid under the influence of favorable temperature and moisture conditions.

Moisture Requirements of Crops.—The amount of moisture required by crops for their best development varies for different localities and for different crops. In studies of this character several modifying influences must be taken into account, which vary widely for different sections of the country. Among these may be mentioned soil texture as affecting its moisture-retaining qualities, temperature conditions, amount of sunshine, and rate of evaporation.

Rainfall required for crop production.—The amount of precipitation required under favorable distribution for the successful production of crops in much of the country east of the Rocky Mountains is considerably less than the average amounts shown in the annual precipitation chart. It is usually considered that between 15 and 20

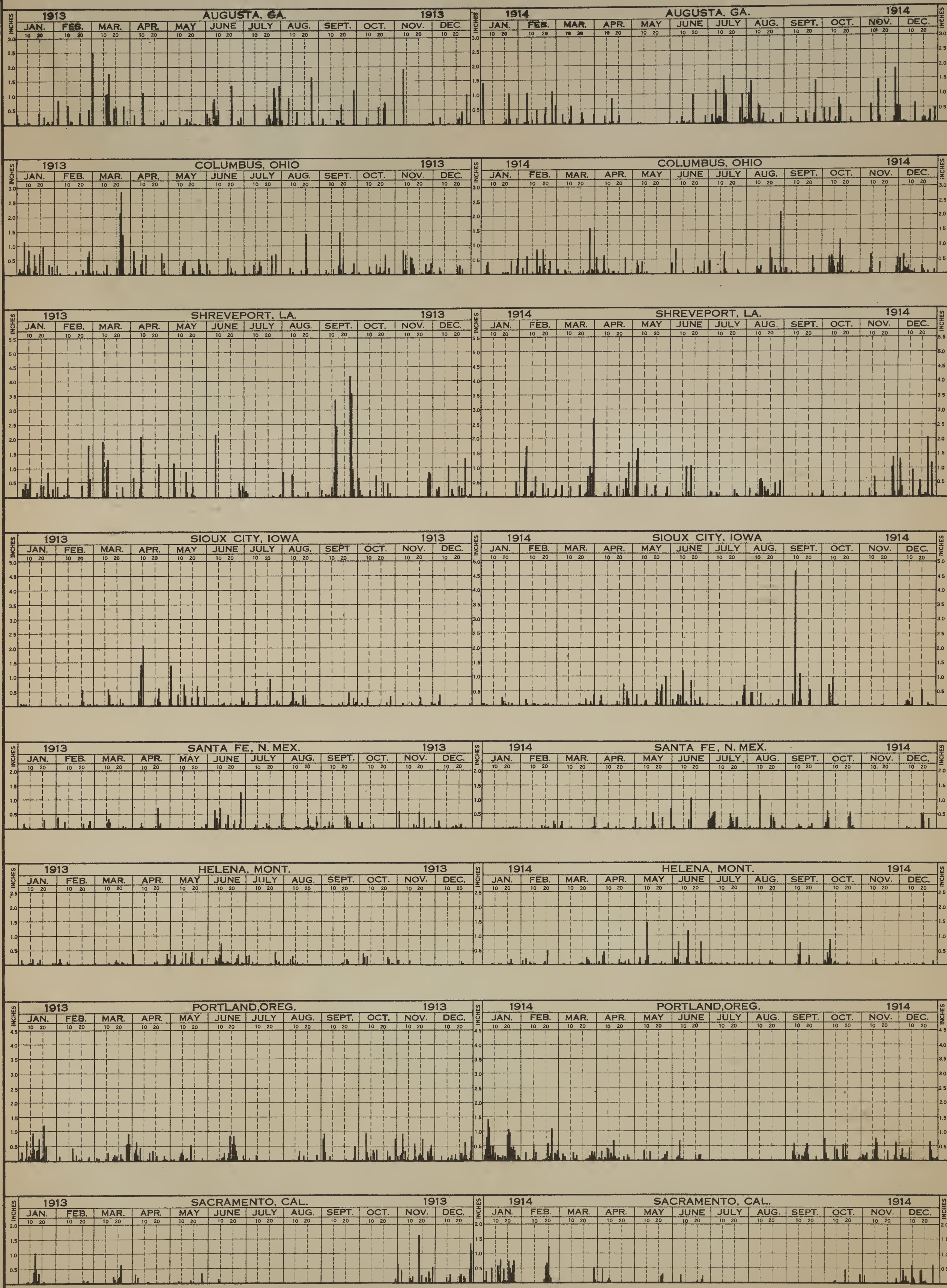
FIGURE 68A

DAILY DISTRIBUTION OF PRECIPITATION
SELECTED STATIONS 1911–1912

Figure 68.—These graphs show for eight selected stations, representing different sections of the country, the daily precipitation during the four years from 1911 to 1914, inclusive. The heights of the vertical bars show the 24-hour amounts of precipitation, in inches, for each day on which precipitation occurred during the period, and the blank spaces between the bars show the intervals between rains. Monthly, seasonal, and annual precipitation data are based primarily on the daily amounts, and the significance of averages depends largely on the character of the daily distribution. For example, average amounts of rainfall in localities where rain occurs at fairly short and regular intervals and usually in moderate amounts have wholly different agricultural significance than identical averages in other localities where rainfall is more irregular in occurrence or torrential in character. The graphs indicate in a general way for the localities of the respective stations the daily distribution of precipitation throughout the year and also illustrate the

FIGURE 68B

DAILY DISTRIBUTION OF PRECIPITATION
SELECTED STATIONS 1913-1914



irregular character of the intervals between rains. It will be noted from the graphs for Augusta, Ga., and Shreveport, La., that occasionally very heavy rainfall may be expected in the Southern States. These heavy rains are of little agricultural value, but they increase the monthly, seasonal, and annual averages to an extent that render these averages not strictly representative from an agricultural standpoint. In the Ohio Valley and in the Plains States, represented by Columbus, Ohio, and Sioux City, Iowa, respectively, heavy rains are not of so frequent occurrence and the intervals between rains are comparatively uniform. In California precipitation is irregular, as shown by the graph for Sacramento, but it is more uniform in western Washington and Oregon, as indicated by the graph for Portland.

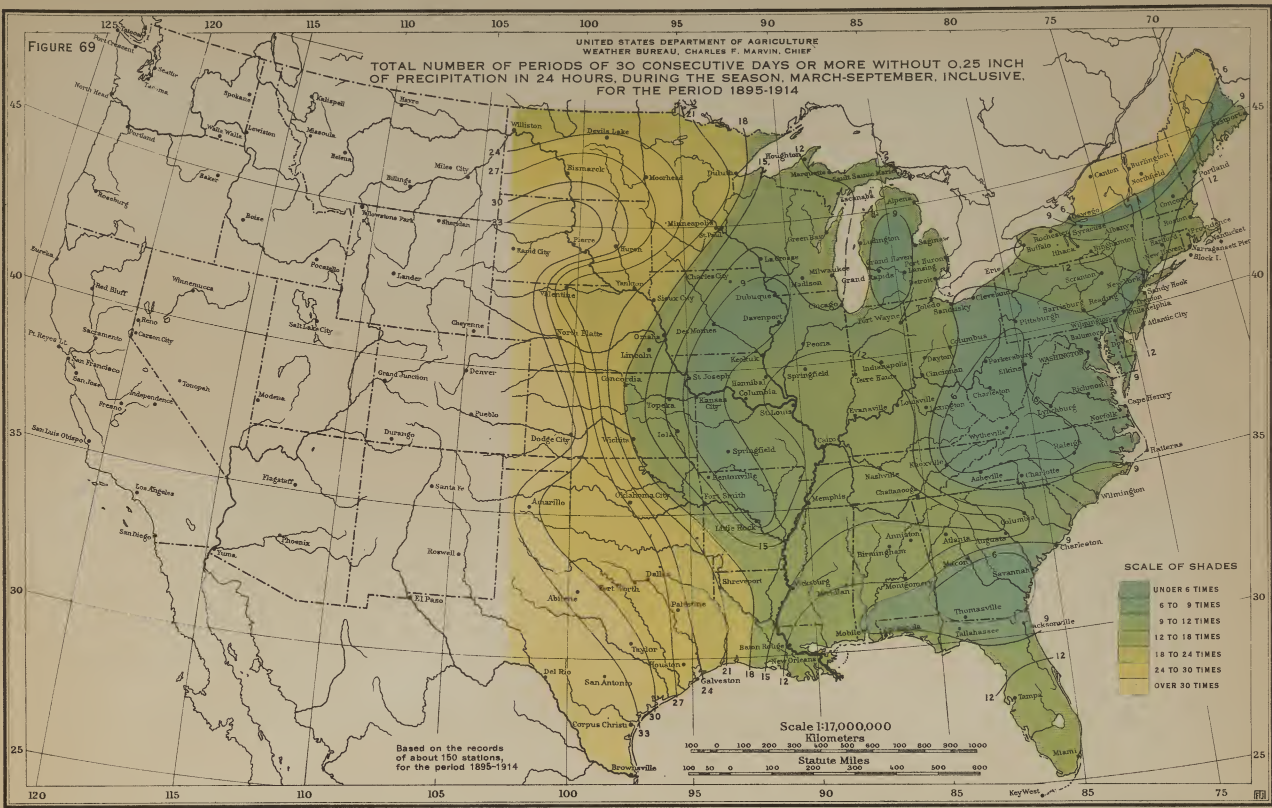


Figure 69.—This chart shows for the season from March 1 to September 30, for districts from the Great Plains eastward, the total number of periods of 30 consecutive days, or more, without one-fourth inch of precipitation in 24 hours, during the 20-year period 1895-1914. The lines are based on the records of all regular reporting stations within the districts mentioned having full 20-year records, about 150 in number. The areas having the fewest such periods of deficient precipitation are found in the Middle and South Atlantic States, the Upper Ohio Valley, and in the northern portions of New York and New England, where such droughts occurred, on the average, about once in every three seasons. Other areas of comparatively infrequent occurrence are found in western Missouri, southeastern Iowa, and in Michigan. The regions of most frequent occurrence are found in the western portions of the Plains States, where the average is nearly two such droughts in each season.

inches of annual precipitation, broadly speaking, determines the dividing line between areas where farming operations can be successfully conducted by ordinary methods and those where irrigation or other special methods are necessary, but no hard and fast rule can be laid down in this connection. With an annual precipitation of only 15 inches other conditions must be very favorable for profitable agriculture by ordinary methods. There are in Montana, eastern Washington, and elsewhere in the Northwest important grain-producing areas which receive, on the average, less than 15 inches of precipitation annually, in fact, wheat is grown in eastern Washington on only 9 inches average annual precipitation, but in these areas special care is given to conserving the moisture of the non-growing period for use during the following growing season. In the great spring-wheat region of the Red River Valley the average annual precipitation is only about 20 inches, and ordinary farming methods obtain.

In considering the moisture requirements of crops in relation to the average precipitation, not only is its seasonal distribution an important consideration, but also the amount of moisture stored in the soil at the beginning of growth, which becomes available independently of the occurrence of subsequent rainfall, must be considered, and also the portion of the rainfall received during the growing season itself which does not become available for plant growth, owing to run-off, evaporation, and other causes. Variations in the amounts of rainfall, especially droughts, are also of great importance.

The amount of stored moisture in the soil at the beginning of the growing season in much of the great grain producing Plains region is usually not large, owing to the scanty winter precipitation, and here successful crop production depends largely on the occurrence of rainfall during the period of actual growth. On the other hand, small grains in the Pacific Coast States depend largely for final maturity on the amount of moisture stored in the soil during the winter, or rainy season.

Amounts of precipitation as large as those shown in the average precipitation charts occur usually in less than half the years, and for the several months of the growing season the precipitation for about one-fourth of the years in some of the principal agricultural regions is only about one-half as much as the 20-year average. Furthermore, a considerable portion of the actual rainfall measured is of no value agriculturally, especially in regions with frequent intense rainfall. For example, 4 or 5 inches, or more, of rain may be recorded in a single day, and 15 to 20 inches in a single month, but while these heavy falls are included in computing the general averages, only a small portion of the water is available for plant development, the larger portion being lost by run-off. Thus the average amount of rainfall does not have the same agricultural significance for different sections of the country, consequently the frequency and amount of heavy rainfall in different localities, as indicated by the various auxiliary graphs and charts, should be considered in using the averages shown on the charts, also in making comparisons of one section of the country with another.

Critical periods in plant growth.—There is undoubtedly for most plants a critical period of growth, differing for species and varieties, during which weather conditions, especially rainfall, largely determine the amount of the final yield.

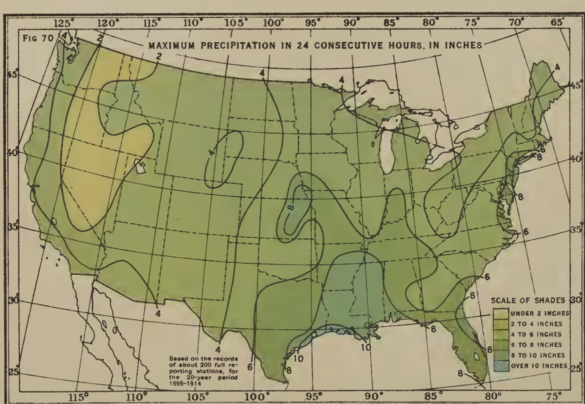


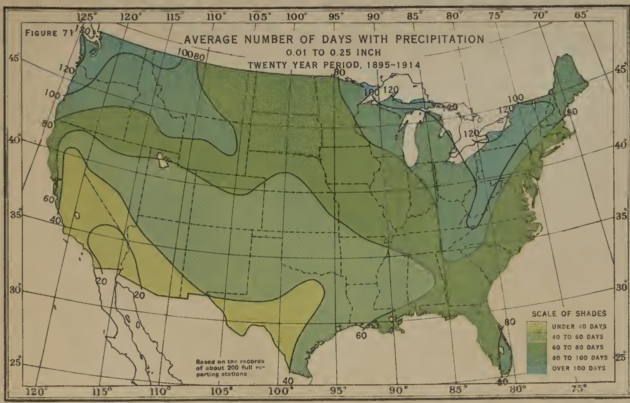
Figure 70.—This chart shows the greatest precipitation in 24 consecutive hours during the period 1895–1914. East of the Rocky Mountains the heaviest rains vary in amount in 24 hours from 4 inches in the Great Plains and Northeastern States to 10 inches along the Gulf Coast in Texas and Louisiana. On the North Pacific Coast, where the annual precipitation is heavier than elsewhere in the United States, the rainfall in 24 hours has never exceeded 5 inches.

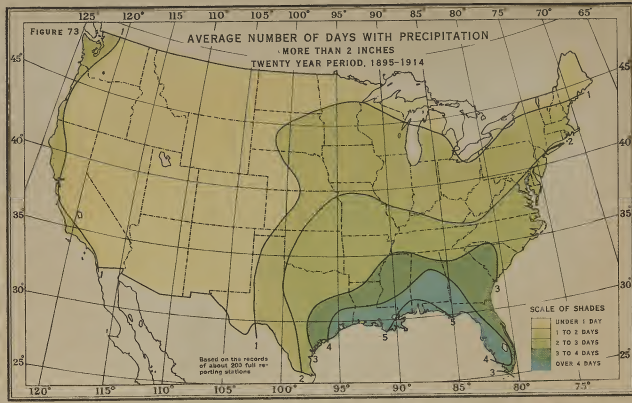
Some of the more important facts established by J. Warren Smith are as follows: In localities where temperature and sunshine are sufficient, rainfall is the controlling factor in determining plant development, and the final yields of both grain and straw, or fodder, are greatest when the soil contains from 40 to 80 per cent of its water saturation capacity during the most active period of growth, the most advantageous percentage of moisture varying for different plants and character of soil. For certain crops the critical period of growth is very short, occurring in some cases just before blossoming and in others soon thereafter. In some cases temperature seems to be the controlling weather factor and in others rainfall, varying with the crop and locality.

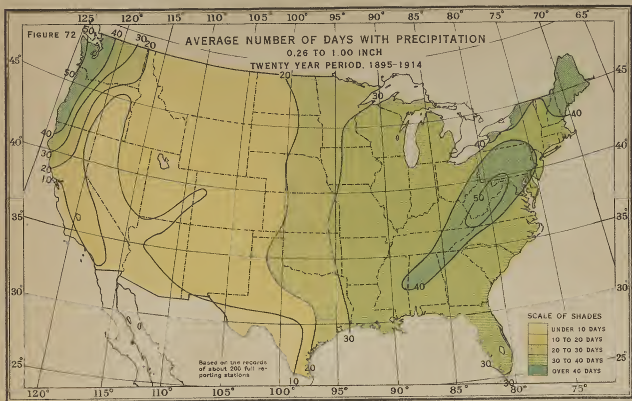
In studies of the relation between weather conditions and the yield of corn in several of the principal corn-producing States, Smith concludes that the critical period of development for that crop is comparatively brief, and that rainfall is the controlling weather factor. Considered by calendar months, the rainfall for July is the most important, but that for the period from the middle of July to the middle of August has a far greater effect upon the yield of corn than for any other similar period, while that for the 10 days following the blossoming period has an almost dominating effect on the yield, the latter varying directly with the amount of rain. In the case of potatoes in Ohio, he finds that comparatively cool and wet weather during July is most beneficial to the development of the crop.

In the case of cotton, the writer has found two critical periods very largely controlled by moisture conditions. One of these includes May and June, when too much rain, especially if accompanied by low temperature, is very detrimental to crop development; the other is in July and August, when deficient moisture, particularly when high temperatures obtain, is very injurious to the crop.

The most favorable conditions for cotton are comparatively dry and warm weather during May and June, and moderate rainfall during July, August, and early September, followed by a cool, dry fall. The most unfavorable are cool and wet weather during May and June, followed by hot and dry weather during the summer. Owing to the long period of growth and the tendency of the fields to become grassy, it is essential for best results that the weather be such as to permit thorough cultiva-







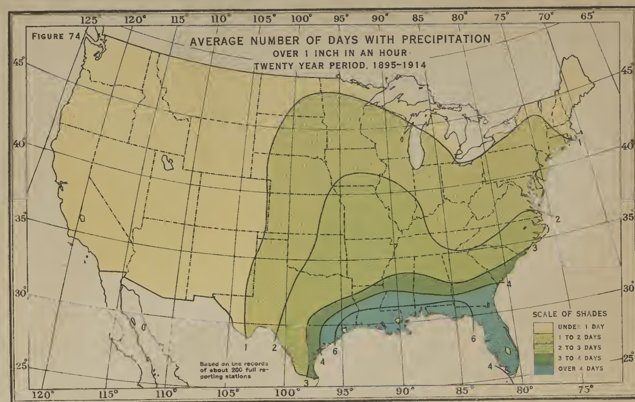


Figure 71.—The average annual number of days with light rains (0.01 to 0.25 inch) ranges from less than 20 in southeastern California to 120 days along the North Pacific Coast and in the upper Great Lakes region.

Figure 72.—The average annual number of days with moderate precipitation (0.26 to 1 inch) ranges from less than 10 in the far Southwest and in portions of the Interior Plateau region to 50 days along the North Pacific Coast and also in the central Appalachian Mountain region.

Figure 73.—The average annual number of days with more than 2 inches of rain ranges from less than one day in most of the Western States and along the Canadian boundary to five days in the central Gulf region.

Figure 74.—The average annual number of days with over 1 inch of precipitation in an hour ranges from less than one day in the Western States and northern Great Lakes region to six days along the Gulf Coast.

tion of cotton during the spring months; too much rain prevents this, and, in addition, such a condition encourages shallow root growth, which proves disastrous if a severe drought follows.

Day and night rainfall.—The inset chart, figure 9, accompanying the map of warm-season precipitation, shows for the 6-month period, April to September, inclusive, the percentage of rainfall occurring between 8 p. m. and 8 a. m., seventy-fifth meridian time. This inset chart is based on records of about 175 regular Weather Bureau stations, covering the full 20-year period 1895–1914.

Rainfall during much of the crop-growing season is largely the result of thundershowers, and droughts of more or less severity are of rather frequent occurrence, but more so in some sections of the country than in others. During periods of deficient rainfall, whether or not showers of small or moderate amounts result in permanent benefit to growing plants depends largely upon the time of their occurrence, whether in the heated period of the day or the comparatively cool night hours. If in the former, the hot sunshine, which frequently is in evidence immediately after summer daytime showers, causes rapid evaporation and often crusts the cultivated surface, in which case little or no benefit is derived from the shower and actual harm may result. On the other hand, when showers occur at night, evaporation is less active, the moisture penetrates the soil to a greater depth, a crust is less likely to form, and a maximum of benefit is derived.

The quantitative relation between day and night rainfall is also of considerable agricultural significance from the viewpoint of interruption to farm work. While rainfall is indispensable to the farmer, it nevertheless entails a loss of time for labor of no small proportions in the aggregate, and as the amount of time so lost by reason of rainy weather varies greatly in different sections of the country, a knowledge of this variation becomes of considerable importance from the standpoint of economical production.

East of the Rocky Mountains there are wide variations in the matter of day and night rains. The region of maximum day rainfall is found in the Southeastern States, where at some places about 75 per cent of the total rainfall for the 6-month period occurs between the hours of 8 a. m. and 8 p. m., seventy-fifth meridian time. From this locality northward and westward there is a progressive and comparatively uniform decrease in the proportion of day rains until the other extreme is reached in the Plains region. Here, from 60 to 65 per cent of the warm season rainfall occurs during the hours from 8 p. m. to 8 a. m., seventy-fifth meridian time. Figures 16 and 17 show for Lincoln, Nebr., representing the region of dominant night rains, and Thomasville, Ga., representing that in which day rains are of greatest relative amount and frequency, the average hourly rainfall, local standard time, for the period April to September, inclusive, and also the average hourly frequency of rains. The diagrams comprised in this figure show also for the stations mentioned and for Evansville, Ind., the

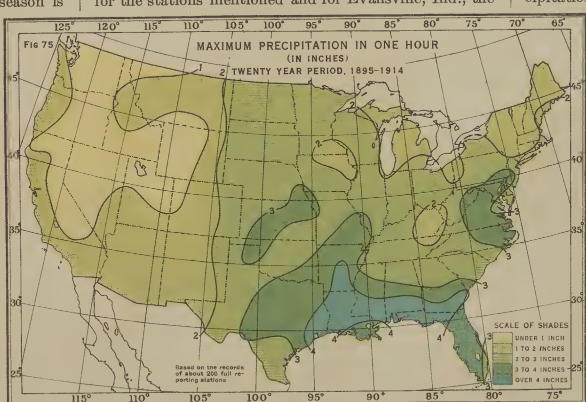


Figure 75.—The heaviest rainfall in an hour observed during the 20-year period 1895 to 1914 ranges from less than 1 inch in most sections west of the Rocky Mountains to about 4 inches in the central Gulf Coast States. In most of the principal agricultural regions east of the Rocky Mountains the maximum rainfall in an hour ranges from 2 to 3 inches, increasing from north to south. Extraordinarily heavy rainfall of torrential type occasionally occurs, however, in Southern California and Arizona.

percentages of the total rainfall and total duration of rains occurring during the respective day and night periods for each of the six months. The record of Evansville is introduced to show conditions for regions in which the night and day rainfalls are of approximately equal amount.

In this connection it is of interest to note that the region of dominant night rainfall is one in which a large amount of wheat is grown, and also that the greatest concentration of night rains comes in the harvest season. The advantages of this nocturnal concentration can not be overestimated, as otherwise great difficulty would be experienced in harvesting and thrashing the immense crop grown. The Plains region is also one of great importance in corn production and the frequent night showers in those districts undoubtedly contribute largely to making it such.

West of the Rocky Mountains the summer rainfall is about equally divided between day and night, except that in the Arizona type there is a marked afternoon concentration. In most of the western districts the question is not of special importance, however, as precipitation is usually light and in large areas negligible.

Frequency and intensity of precipitation.—In studying the relation of precipitation to plant development, the question of frequency of occurrence and intensity of fall becomes of great importance. The average precipitation in a given locality may be considerably less than in some other, but the rains may be better distributed and less torrential, which would largely offset the difference in actual amounts. Only the water actually absorbed by the soil can be utilized in plant development, and therefore in using charts of average rainfall the frequency and intensity should be known, as they are indicative of the probable proportion of the actual precipitation that finally becomes available for growing plants.

Accompanying the charts of average seasonal and monthly precipitation there are others that show for the several months and seasons the frequency of occurrence, as indicated by the average number of days on which precipitation to the amount of 0.01 inch or more occurs. It will be noted, for example, by referring to these charts that while the average amounts of precipitation over the eastern sections of the country increase from the Northern States southward to the Gulf region, the frequency of occurrence often increases in the opposite direction, from south to north, this condition being especially marked during the spring months. Thus, where the total precipitation is comparatively small, rain often occurs at shorter intervals, which largely compensates for the smaller amount. This is, of course, not a general rule applicable to all parts of the country and seasons of the year. In the western semiarid sections, where the precipitation is very light, there is also a correspondingly small number of days with rain, and where it is heavy, as along the North Pacific Coast, the number of rainy days is large.

Figure 76.—This chart shows the average annual snowfall in inches unmelted. East of the Rocky Mountains lines have been drawn at 1 inch and for each 10 inches of snowfall, but in the western mountainous districts snowfall conditions are so varied that wider intervals had to be used and the areas are broadly generalized. Here figures also have been entered on the map to show the average amount at as many localities as practicable. The heaviest snowfall in the United States occurs in the mountains of the Pacific Coast States, where in some localities the averages are as much as 400 to 500 inches. In the Rocky Mountains snowfall is not so heavy as in the Sierra Nevadas and Cascades, but here also large amounts frequently occur, some of the western slopes receiving from 200 to 300 inches, or more. East of the Rockies the heaviest snowfall occurs in the northern border States from Michigan to New England. In some localities in these Northeastern States from 120 to 150 inches occur annually on the average. The amounts decrease rapidly southward to the Gulf region, where snowfall is usually negligible in amount.

West of the Rocky Mountains, for the winter season as a whole, December to February (fig. 27), the total number of rainy days varies from about 5 or 6 in southwestern Arizona and the adjoining portions of California and Nevada to about 60 days along the North Pacific Coast. Over the western portion of the Plains region, extending from the Canadian boundary to the Mexican border, there are about 10 days with precipitation during this period. To the eastward there is a progressive increase in the frequency of precipitation to from 30 to 40 days in the region just west of the Appalachian Mountains, but in the Middle and South Atlantic States the number is smaller, especially in the Florida Peninsula.

For the spring season, March to May (fig. 37), the number of rainy days is materially less than for winter in the Pacific Coast States, and also in the central and east Gulf region, but over the Great Plains precipitation occurs much more frequently, the number of days for the season ranging from about 20 in the western portion to about 30 in the eastern.

During the summer season, June to August (fig. 47), the average frequency of rainfall is comparatively uniform over most districts east of the Rocky Mountains, there being generally for the season from 20 to 30 days with rain throughout the Mississippi Valley and 30 to 40 days to the eastward. In much of California there is on the average only about one day with rain for the entire three months, but this increases northward to about 20 days along the Washington coast.

During the three fall months, September to November (fig. 57), rainfall is less frequent in most eastern districts than in the other seasons, the number of rainy days for this period east of the Rocky Mountains ranging generally from about 10 to 20, except in the Great Lakes region and Ohio Valley and also over the Appalachian Mountain region and in the Northeastern States, where precipitation is of more frequent occurrence. In the Pacific Coast States the number of rainy days for the season ranges from 10 or less in central and southern California to more than 40 along the Washington coast.

Figure 68 shows graphically for eight selected stations the daily rainfall for each of the four years from 1911 to 1914. It indicates in a general way for the localities of the respective stations the distribution of precipitation throughout the year and also the irregularities of the intervals between rains.

The relative intensities of rainfall for short periods of time in different portions of the country are shown by figures 70 to 75. Figure 71 shows the annual average number of days with precipitation from 0.01 to 0.25 inch, figure 72 shows the average annual number with 0.26 to 1 inch, figure 73 shows the average annual number of days with more than 2 inches, and figure 74 the average annual number with more than 1 inch in an hour. Figure 75 shows the maximum precipitation in one hour during the entire 20-year period 1895 to 1914, and figure 70 the maximum in 24 hours during the same period. These charts indicate the frequency of light and of heavy rainfall in different sections of the country.

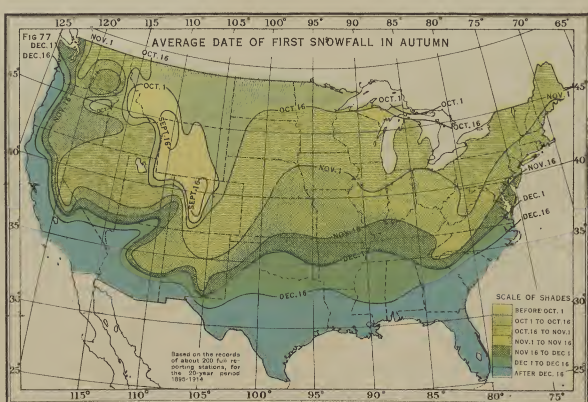


Figure 77.—This chart shows the average date of the first snowfall in autumn. These dates range from somewhat earlier than September 16, locally, in the Rocky Mountain region, and October 1 in extreme northern Michigan, to about December 16 in the central portions of the South Atlantic and Gulf States. To the southward of this line the occurrence of snow is very irregular, or, as along the Gulf Coast, often entirely lacking.

Droughts.—Just what deficiencies in precipitation constitute damaging droughts is not easy of determination, as many modifying factors enter into the question, such as temperature, soil texture as affecting its moisture retaining qualities, condition and kind of exposed plants as regards critical periods of growth and drought resisting qualities, moisture condition of the soil at the beginning of the period of deficient rainfall, and others. It is likewise difficult to determine the most satisfactory method of presenting precipitation data to show best the frequency of occurrence of deficient rainfall that may be harmful or disastrous to growing crops. Statements as to the departures from the average amounts are not always entirely satisfactory, for the reason that the normal amounts vary greatly in different sections of the country and consequently a given percentage of minus departures for an extended period in a region of usually abundant rainfall would not be so serious as a similar deficit in one where the average amount is barely sufficient for the development of the staple crops. Droughts of more or less severity occur at irregular intervals in all parts of the United States and they may affect areas of considerable extent, but one never covers the entire country. On the other hand, they may be extremely local, affecting only a county or even part of a county.

The frequency of periods of subnormal rainfall for the different portions of the country and the magnitude of deficiencies are shown graphically by several methods in the accompanying charts and diagrams. A dot map, figure 15, shows for a large number of representative and well-distributed stations the monthly distribution of precipitation for different sections of the country for each month of the entire 20-year period 1895 to 1914. The frequency of subnormal monthly precipitation in different localities can readily be seen from these graphs. Figure 7 shows for the entire country the relative number of times in the 20-year period 1895 to 1914 that the annual precipitation was less than 85 per cent of the average; figure 11 shows the relative number of times the warm season amount, April to September, inclusive, was less than 75 per cent of the average, while figures 58 to 65 show for each month from March to October, inclusive, the relative number of times the monthly totals were less than 50 per cent of the average. These charts are based on the records of about 600 well-distributed stations.

There are wide variations in the frequency of periods of subnormal rainfall in different portions of the country, even in comparatively small areas in close proximity, especially when monthly periods are considered. West of the Rocky Mountains the charts show very large percentages, particularly in the summer season, because the monthly amounts in those districts are usually very small and the averages are unduly magnified by the occasional occurrence of comparatively heavy rainfall.

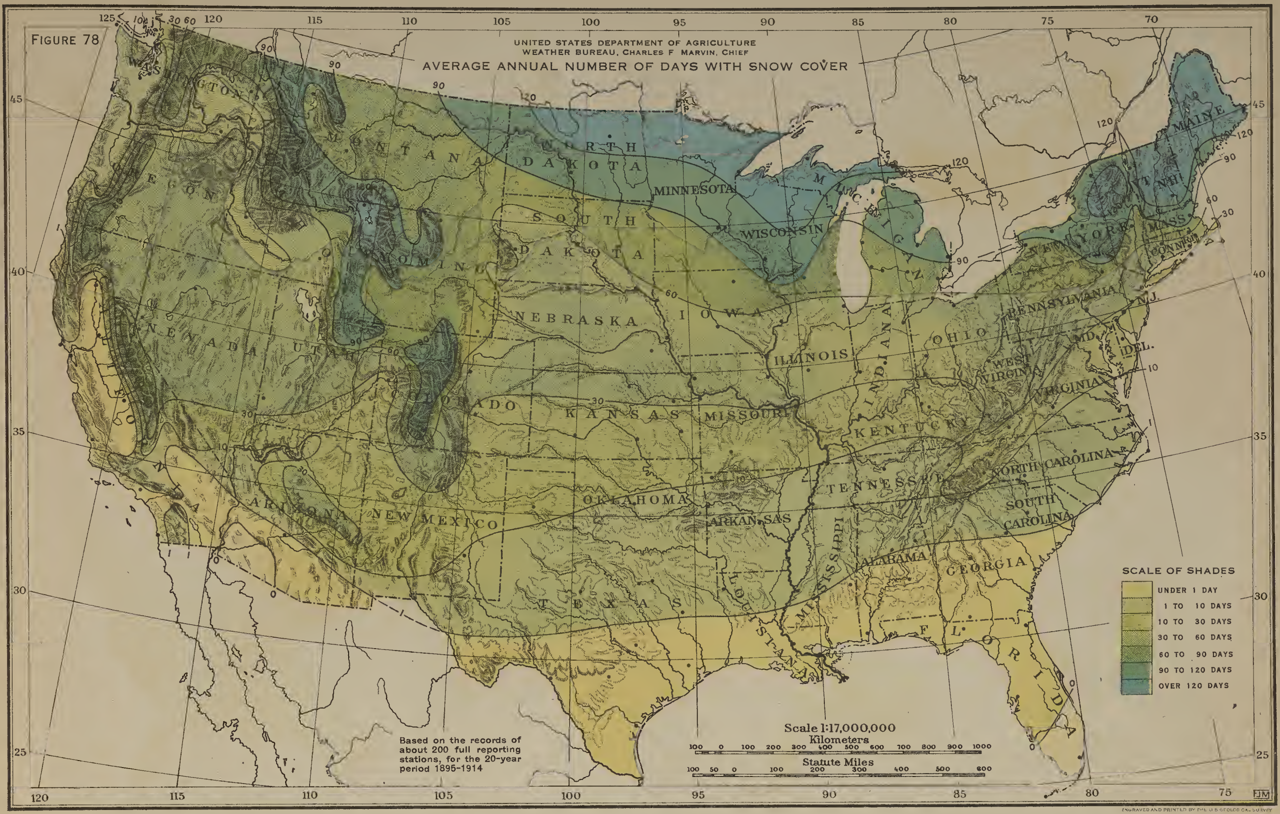


Figure 78.—This chart shows the average annual number of days with snow cover; that is, the average number of days during which the ground is covered with snow, but not necessarily consecutive days. The chart indicates the duration of protection afforded fall-sown grains by snow cover in different sections of the country. East of the Rocky Mountains the average number of days with snow on the ground during the season decreases with considerable regularity from about 120 along the northern border to one day in the central portion of the Gulf States. From the Rocky Mountains westward the data refer only to the lower altitudes, no attempt having been made to show conditions in the more elevated districts.

Figures 66 and 69 show for the districts east of 103° west longitude the number of times in the season, March to September, inclusive, that precipitation to the amount of 0.25 inch in 24 hours did not occur for 20 or more consecutive days and for 30 or more consecutive days, respectively; while figure 67 shows for the same season and for each of the 20 years at selected stations, arranged by geographic districts, the longest period of consecutive days during which precipitation to the amount of 0.25 inch in 24 hours did not occur. These charts are based on the records of all full-reporting stations in the districts covered, about 100 in number, for the 20-year period 1895–1914.

SNOWFALL.

Figure 76 shows the average annual snowfall unmelted, in inches, for the United States. East of the Rocky Mountains lines have been drawn in most cases for each 10 inches, but in the western mountainous districts snowfall conditions are too varied to permit of a satisfactory presentation of the data by this means. The difficulties in depicting the precipitation of these districts, which includes melted snow, have previously been pointed out. The water equivalent of snow varies with its physical condition, whether moist or dry, and the ratio may have a range of from 1 to 5 to 1 to 15 or even less. In addition, precipitation often occurs in the valleys in the form of rain and on the mountains as snow, which makes the differences in snowfall between the valleys and adjacent mountains much larger than the actual difference in precipitation. As an indication of the magnitude of the difference in the amount of snowfall that may occur in near-by localities, owing to topographic influence, the records at Electra and Tamarack, Cal., may be cited. Electra is situated in Amador County at an elevation of 725 feet above sea level. At this station the average annual snowfall for the 10-year period 1906–1915 was about 1 inch. Tamarack is located some 50 miles to the eastward, in Alpine County, but at an elevation of about 8,000 feet, and here the average annual snowfall for the same period was about 42 feet, the amounts being in the ratio of about 1 to 500. In view of these facts no attempt was made to draw lines of equal snowfall in detail for the western districts, and here the areas inclosed by the various lines are broadly generalized. The annual average amounts of snowfall have been entered numerically for as many localities as practicable.

More or less snow occurs in all portions of the United States, except in southern Florida and at the lower elevations in southwestern Arizona and southern California. Snow is of common occurrence at the higher altitudes in California but is practically unknown along the immediate coast south of latitude 42°.

The greatest known snowfall in the United States occurs on the west or windward side of the Sierra Nevada and Cascade ranges in the Pacific Coast States, where at some places average amounts of 400 to 500 inches or more are of record. At Summit, Cal., situated in a pass of the Sierra Nevada at an elevation of about 7,000 feet, the annual average snowfall is in excess of 400 inches, while 697 inches, or nearly 60 feet, have been recorded in a single season and 298 inches, or about 25 feet, in a single month. Tamarack is about 1,000 feet higher than Summit and its annual average snowfall is about 100 inches greater. At some places to the northward, over the western slopes of the Cascade Range in Oregon and Washington, from 300 to 400 inches or more of snow occur each year on the average, but to the leeward of those mountains the lower altitudes receive only from 12 to 20 inches.

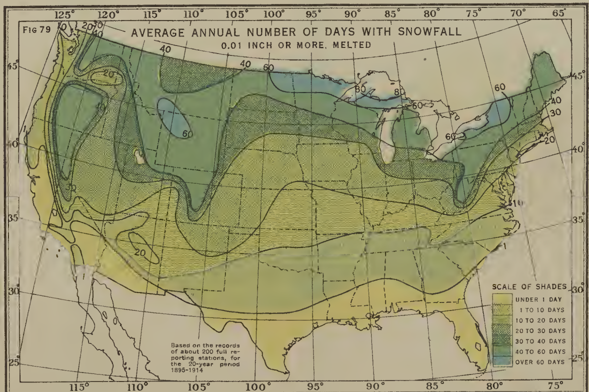


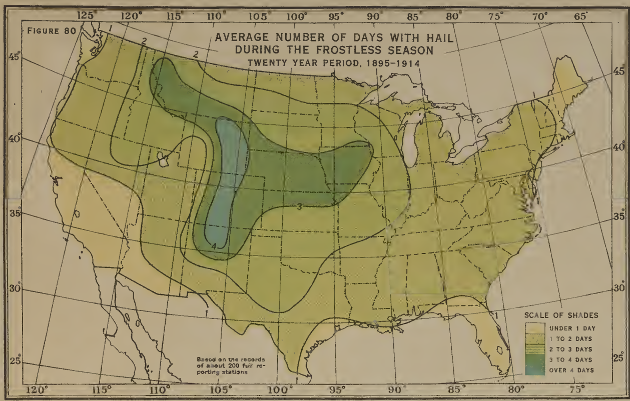
Figure 79.—This chart shows the average annual number of days in which snow falls. The number varies from 80 in extreme upper Michigan to 1 day in the central portion of the Gulf States. From the Rocky Mountains westward the data refer only to the lower altitudes, snow being more frequent in the higher mountains than indicated on the chart.

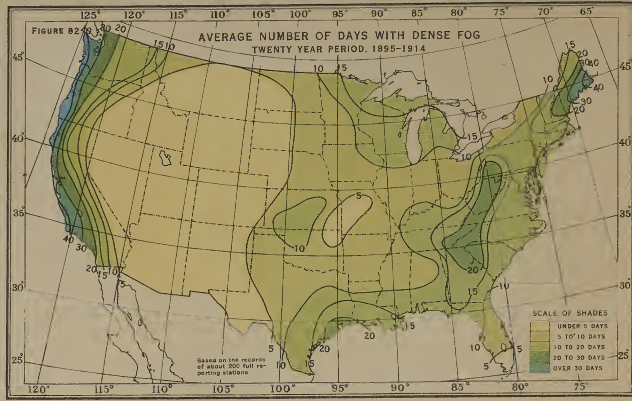
In the Rocky Mountains snowfall is not so heavy as in the Sierra Nevada and Cascade ranges, but here also large amounts frequently occur, especially on the western slopes. In Colorado the average annual amounts at some of the higher elevations reach 300 inches and at similar locations in northern New Mexico and in Wyoming about 200 inches occur. In some mountainous districts of Idaho the average snowfall is also about 200 inches.

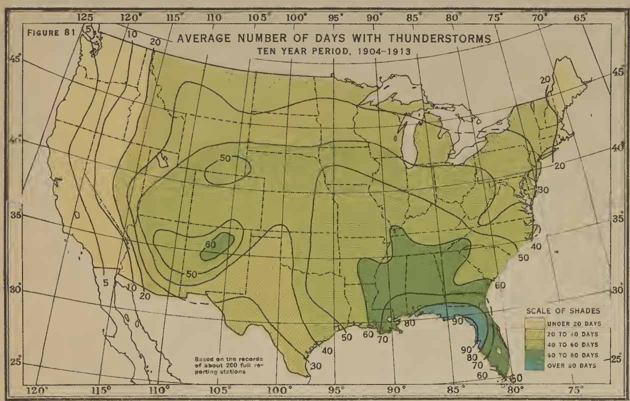
East of the Rocky Mountains the regions of heaviest snowfall are to be found in portions of the Upper Peninsula of Michigan, where the average annual amounts reach 120 inches or more, and at places in the Adirondack Mountains in New York, where 150 inches or more occur on the average. There is also an area of heavy snowfall over the central section of the Appalachian Mountains, including western Maryland and portions of West Virginia, where from 80 to 100 inches are received annually on the average. From these heavy snowfalls in the northern border States and mountainous regions there is a rapid decrease southward to about 20 inches in central Virginia and the southern portions of Ohio, Indiana, and Illinois, and thence a less rapid decrease to the Gulf States, where the amount of snowfall is usually negligible. Over the Great Plains the average annual snowfall ranges generally from about 1 inch in central Texas to about 20 inches in northern Kansas, while farther north from 20 to 30 inches are received.

Figure 78 shows the average annual number of days with snow cover; that is, the average number of days in the winter season during which the ground is covered with snow, but not necessarily consecutive days. This chart shows the relative protection usually afforded fall-sown grains by snow cover in different sections of the country. East of the Rocky Mountains the average number of days with snow cover decreases with considerable regularity from about 120 along the northern border to 1 day in the central portions of the Gulf States. From the Rocky Mountains westward the data refer only to the lower altitudes and no attempt has been made to show the number of days with snow cover in the more elevated regions.

Figure 79 shows the average annual number of days with snowfall (0.01 inch or more, melted), and figure 77







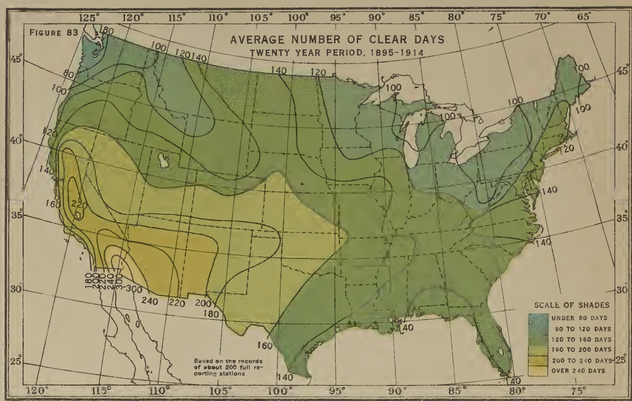


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Figure 80.—This chart shows the average annual number of days with hail between the time of last killing frost in spring and the first in autumn. The length of the season on which the chart is based varies for different sections of the country and for each year, corresponding with the length of the frostless season.

Figure 81.—Thunderstorms are rare in the Pacific Coast States, where they occur, as a rule, on less than five days in the year. They are of greatest frequency along the west coast of the Florida Peninsula.

Figure 82.—Fog is of most frequent occurrence along the Pacific Coast and the northern portion of the Atlantic Coast. Dense fog occurs along these coasts, on the average, during more than 40 days of the year. In the interior districts west of the Appalachian Mountains fog is infrequent, especially in the Rocky Mountain and Interior Plateau regions, where it occurs, as a rule, on fewer than five days annually.

Figure 83.—This chart shows the average annual number of clear days. Cloudy weather occurs with greatest frequency along the North Pacific Coast and in the region of the Great Lakes, where there are, on the average, fewer than 100 clear days during the year. In portions of the far Southwest 300 or more days of the year are clear.

the average date of the first snow in autumn. In these cases, also, the data for the Western States refer only to the lower levels.

HAIL.

Figure 80 shows the average annual number of days with hail during the frostless or crop-growing season, based on the records of all full reporting stations for the 20-year period 1895–1914. The length of the season covered by this chart for different localities is not the same, as the period between the last killing frost in spring and the first in fall has been considered in each case, and this period varies with latitude, altitude, etc. Hail occurs with much greater frequency in the Plains States and the Rocky Mountain region than in other portions of the country. In central and southern California and along the immediate Atlantic and Gulf coasts it seldom occurs, and, in general, it is infrequent east of the Mississippi, occurring in these districts on the average only about once during the frostless season of each year.

The occurrence of hail does not necessarily result in serious damage to crops, as the fall may be only of small amount, doing no harm. This fact should be borne in mind when considering the greater number of these storms over the western Plains and central Rocky Mountain region, as compared with other portions of the country. Hailstorms are often extremely local in character; great damage may be done on a single farm while others adjoining may escape unharmed.

FOG.

Two degrees of fogginess are recognized by the Weather Bureau and recorded at all full reporting stations, namely, "light" and "dense." Fog sufficiently dense to obscure objects at a distance of 1,000 feet from the observer is recorded as "dense," otherwise as "light."

Figure 82 shows for the different portions of the country the average annual number of days with dense fog, based on records of all full reporting Weather Bureau stations for the 20-year period 1895–1914. The regions of greatest fog frequency are found along the Pacific and North Atlantic coasts, over the central and southern portions of the Appalachian Mountain region and along the western Gulf Coast. The region of least frequency comprises the districts between the Rocky Mountains and the Pacific Coast States, where, as a rule, there are fewer than five foggy days during the year. Fog generally is of infrequent occurrence throughout the interior portion of the country, most of those districts having on the average fewer than 10 days with dense fog during the entire year. The occurrence of fog is not of special agricultural significance, although it sometimes contributes appreciable moisture to plants during dry periods, especially on the Pacific Coast.

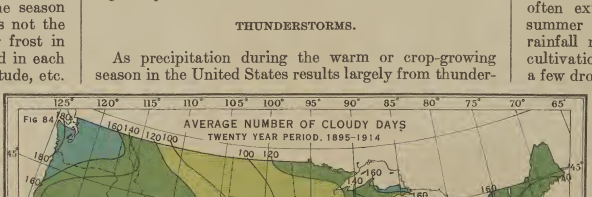


Figure 84.—This chart shows the average annual number of cloudy days. In extreme upper Michigan there are on the average about 160 cloudy days during the year and along the extreme North Pacific Coast about 180 days are cloudy. The fewest number of cloudy days are found in southwestern Arizona and the southeastern portion of California, where, as a rule, fewer than 20 days of the year are cloudy. Partly cloudy days, as classified by the observers of the Weather Bureau, are not included in this chart.

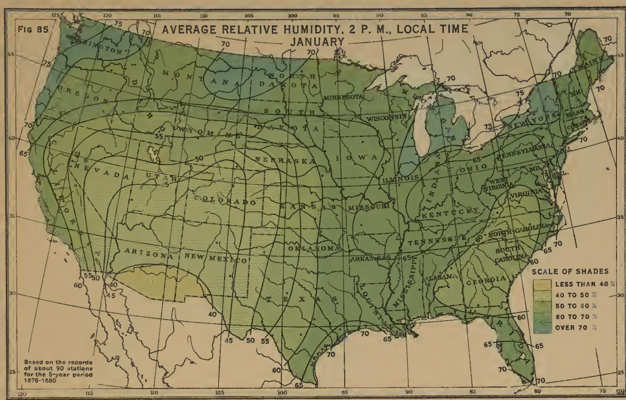
THUNDERSTORMS.

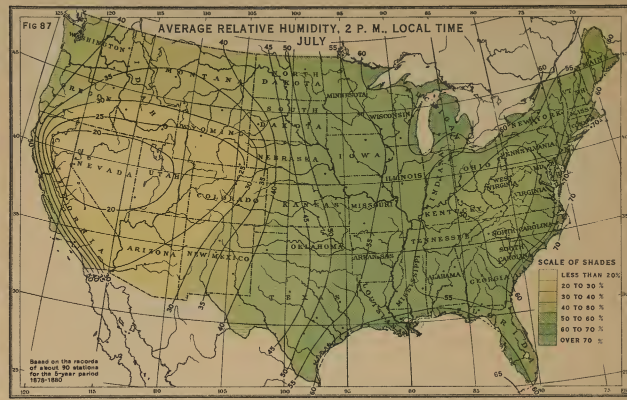
As precipitation during the warm or crop-growing season in the United States results largely from thunderstorms, these local atmospheric disturbances are of great importance agriculturally. They are caused by atmospheric convection, or a vertical interchange of air masses of different temperatures and humidities. There are two recognized classes of thunderstorms, which have been designated "heat" thunderstorms and "cyclonic" thunderstorms. Those of the first-named class usually develop on hot summer afternoons in regions of weak barometric gradient and moist, quiet air; while those belonging to the other class occur under the influence of cyclonic storms, more frequently in the southeast quadrant of the low-pressure area. The breaking up of a long heated period is frequently attended by thunderstorms of rather marked severity which are more or less connected with cyclonic action, as the breaking-up process is usually accomplished by a cyclonic wind movement relieving the stagnant air condition.

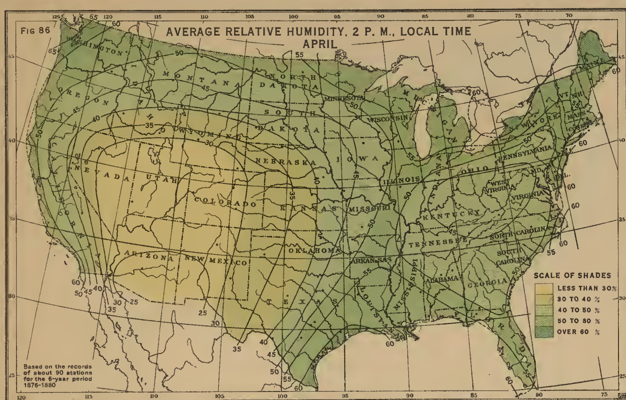
Thunderstorms and the resulting precipitation are often extremely local in character, especially in the summer season. Occasionally in a single small field rainfall may occur in one portion sufficient to delay cultivation temporarily, while in another portion only a few drops fall. Thunderstorms are sometimes severe in character and accompanied by destructive wind and hail. The area of destruction is usually not extensive for an individual storm, but several may occur in quick succession on the same day. Excessive rainfall during short periods of time is often the result of thunderstorm activity, particularly during the summer season.

Figure 81 shows the average annual number of days with thunderstorms for the different sections of the United States, based on the records of all regular reporting Weather Bureau stations, about 200 in number, for the 10-year period 1904–1913. It will be noted from this chart that the region of greatest frequency is to be found along the central and eastern Gulf Coast, where thunderstorms occur on 80 to 90 days annually, and that the smallest number is in the Pacific Coast States, where, as a rule, they are recorded on from two to four days a year only.

The month of fewest thunderstorms is January, when, as a rule, they occur on one or two days only in the region of their greatest frequency, which comprises the Gulf States. July and August have the greatest number, the area of maximum frequency for these months being along the eastern Gulf Coast, where they occur in each month on an average of about 20 days. Thunderstorms are frequent during these two months also in the far Southwest, resulting in the Arizona type of precipitation.







Figures 85 to 88 show the average relative humidity, in percentages of saturation, at 2 p. m. local time, for the months of January, April, July, and October. These charts are based on the records of about 90 stations for the 5 years 1876 to 1880, inclusive, during which time humidity observations were made regularly at all of the then full-reporting stations of the Weather Bureau. These records embrace the only extensive relative humidity data that have been made at the same hour of local time throughout the country, and are thereby comparable for the different sections. However, the period covered is comparatively short and the psychrometric tables employed in reducing the observations, as well as the manner of observing the instruments, have since been revised, which render the data not directly comparable with averages for longer periods and for more recent years. The average minimum relative humidity for the 24-hour period does not differ greatly from the average at 2 p. m., except that in most seasons of the year the minimum relative humidity usually occurs a little later than this hour and is a little lower. For some purposes, therefore, figures 99, 100, and 101, which are based on more recent and extensive data, may preferably be used instead of the maps above.

HUMIDITY.

The humidity of the atmosphere is of great climatic importance, not only from the standpoint of its influence on bodily comfort, but also because of its direct relation to plant life and its bearing on commercial and other activities. In discussing atmospheric moisture four terms are in common use—"absolute humidity," "relative humidity," "the temperature of the dew point," and "depression of the wet-bulb temperature."

FIGURE 89

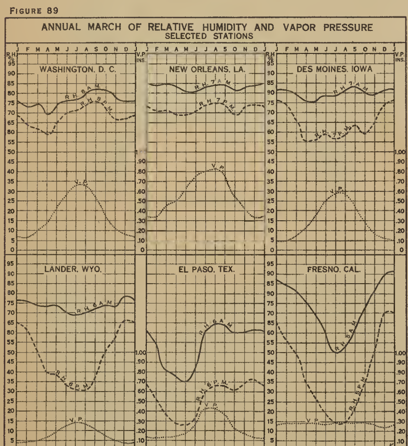


Figure 89 shows for selected stations the annual march of relative humidity and vapor pressure. The relative humidity values for the several months represent averages for each of the regular 8 a. m. and 8 p. m., 75th meridian time observations, with the hour of local standard time at which they were made indicated on each curve. The vapor pressure curves are based on observations made at 8 a. m., 75th meridian time, but these do not differ much from the daily averages, as the diurnal variations in vapor pressure are usually small. The relative humidity values are given in percentages of saturation and the aqueous vapor in inches of barometric pressure.

Absolute humidity is the actual amount of moisture in the atmosphere, usually expressed in inches of barometric pressure, in this case called "vapor pressure," but sometimes it is given as the actual weight of moisture present in a unit volume of air. By relative humidity is meant the ratio the amount of moisture present in the atmosphere bears to the amount that could exist without condensation under the same conditions of temperature and atmospheric pressure. The dew point is the temperature at which saturation occurs and the condensation of the invisible aqueous vapor begins. The depression of the wet-bulb temperature is the difference in temperature registered by a thermometer whose bulb is covered with saturated gauze or other freely evaporating surface and that registered by an adjacent ordinary dry-bulb thermometer. The amount of this depression varies inversely with the relative humidity, provided the temperature remains unchanged.

ABSOLUTE HUMIDITY.—The actual amount of moisture in the atmosphere depends upon the temperature, and to a less extent upon the location with respect to large bodies of water, the latter being the principal source of supply. The diurnal fluctuations are comparatively small and are due largely to the varying rate, from day to night, of evaporation from moist surfaces and to condensation; i. e., precipitation, dew, etc. The maximum, consequently, usually occurs during the day and the minimum during the night.

The seasonal variations in absolute humidity are large, there being usually from two to four times as much moisture in the atmosphere in midsummer as in midwinter. Figure 89 shows for selected stations the annual march of absolute humidity as measured by vapor pressure, and figures 102 and 106 show the average vapor pressures in different portions of the United States for January and for July. The seasonal curve of vapor pressure follows closely the trend of that of temperature.

RELATIVE HUMIDITY.—The absolute humidity in the atmosphere is not so important climatically as the relative amount, since it is the latter that determines whether the climate of a place is physically moist or dry (with reference to its general temperature conditions). Climates recognized as dry are not necessarily deficient in actual atmospheric moisture since even in a desert the absolute humidity may equal or exceed that in a climate usually considered as moist. Figure 106 shows that in southwestern Arizona, commonly referred to as one of the driest localities in the United States, there is in July more moisture in the atmosphere than at points on the Great Lakes, where the climate is considered moist. The physical effect of the moisture condition of a locality is much more clearly indicated, therefore, by the relative humidity than by the actual amount of aqueous vapor present in the atmosphere.

DEPRESSION OF THE WET-BULB TEMPERATURE.—The depression of the wet-bulb temperature varies inversely with the relative dryness of the atmosphere, provided there is no change in temperature. Charts 103, 104, and 105 show for the months of April, July, and October the computed average daily depression of the wet-bulb temperature at the time of minimum relative humidity, which corresponds to the time of maximum temperature. Owing to the large depression of the wet-bulb in the far Southwest the high summer temperatures experienced are not so oppressive as appears to be indicated by the dry-bulb thermometer readings alone, since the dryness of the atmosphere increases the opportunity for evaporation and thus reduces the sensible temperature.

FIGURE 90

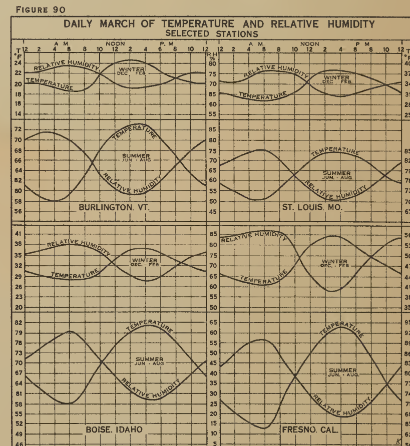
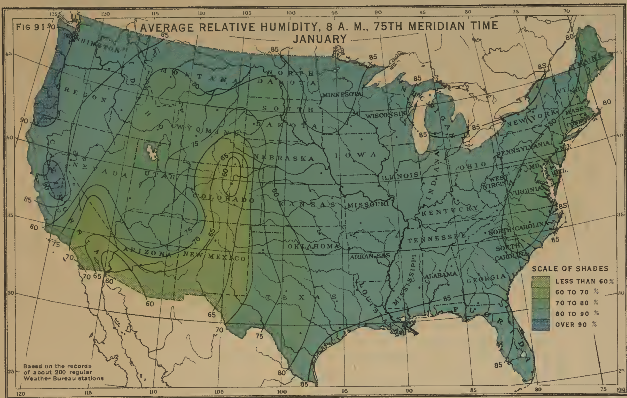
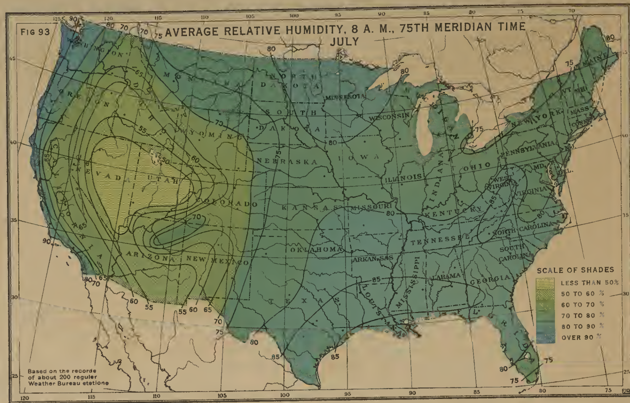
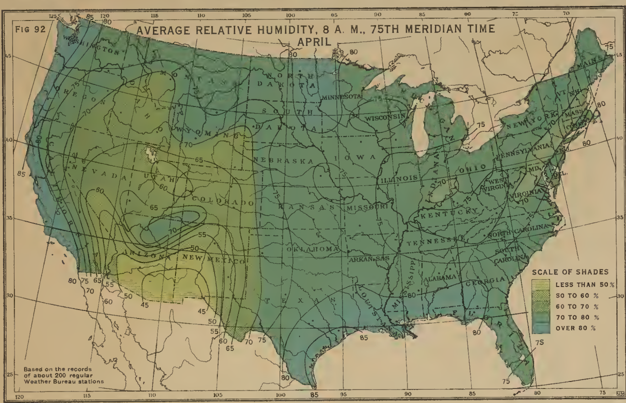
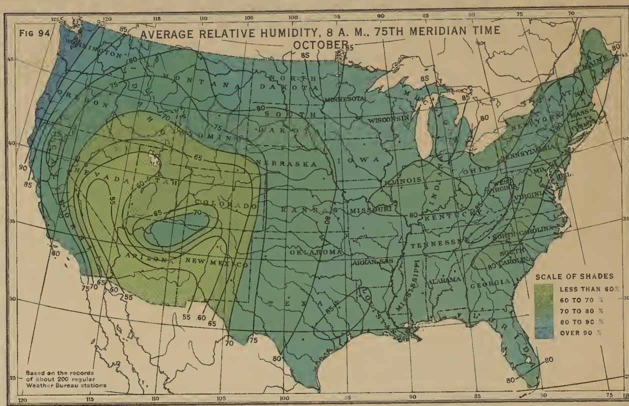


Figure 90 shows for selected stations the diurnal march of relative humidity and temperature. The diurnal march of relative humidity is pronounced and corresponds closely, but inversely, to the daily temperature curve. For each change of 1 degree in temperature there is, on the average, a corresponding change, but in an opposite direction, of from 1.5 to somewhat more than 2 per cent in relative humidity, depending upon the locality. The maximum relative humidity of the day occurs usually near the time of sunrise and the minimum from two to four hours after noon, or the reverse of the hours of occurrence of the maximum and minimum temperatures.

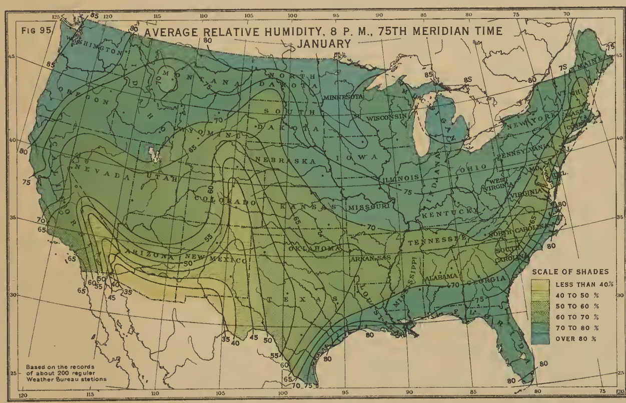


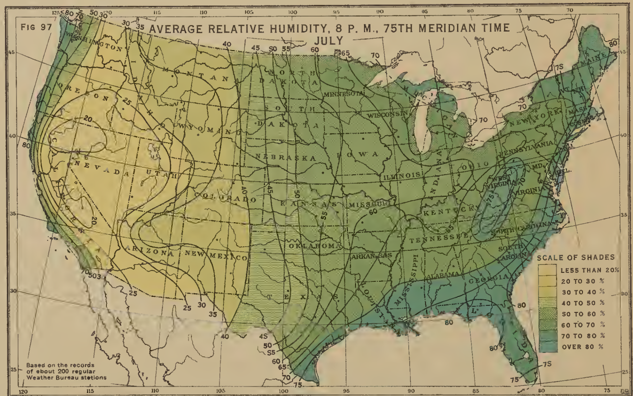


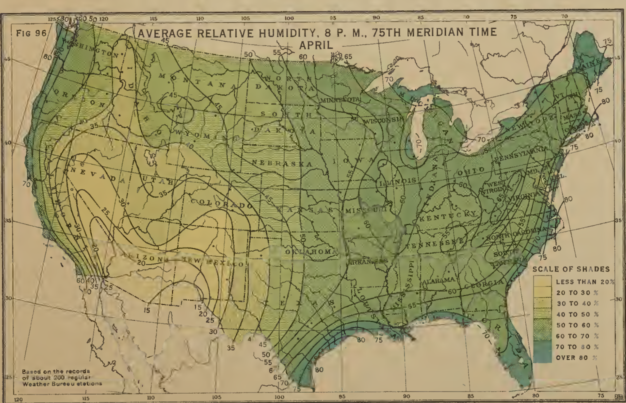


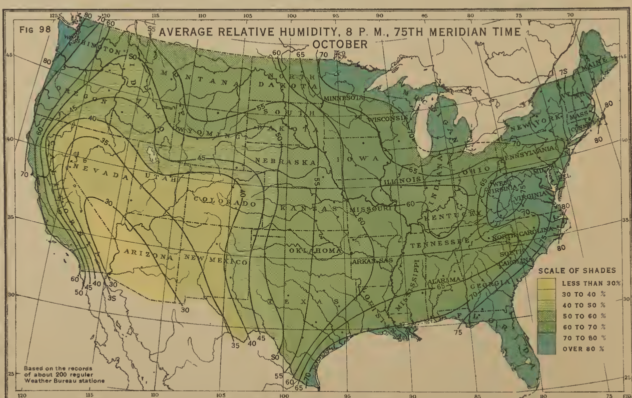


Figures 91 to 94 show for the mid-season months, January, April, July, and October, the average relative humidity at 8 a. m., 75th meridian time, for the 25-year period 1888–1913. These data, and the corresponding data for 8 p. m., figures 95 to 98, are the most extensive observations of relative humidity made by the Weather Bureau, but are not strictly comparable for different sections of the country, owing to the difference in local time at which the observations were made at the various stations, being three hours earlier in the day in the extreme West than in the extreme East. The 75th meridian passes nearly through Philadelphia, and the observations are taken at 8 a. m. standard time in the Eastern time belt, 7 a. m. in the Central time belt, 6 a. m. in the Mountain time belt, and 5 a. m. in the Pacific time belt. The values for the 8 a. m. observations are considerably higher than the daily averages and those for the 8 p. m. are appreciably lower, the departures from the daily mean becoming increasingly greater with progress westward, due to the earlier local time. West of the Rocky Mountains the 8 a. m. values approach the maximum for the day and the 8 p. m. are near the minimum, the averages of the two observations representing in these districts very nearly the 24-hour mean.

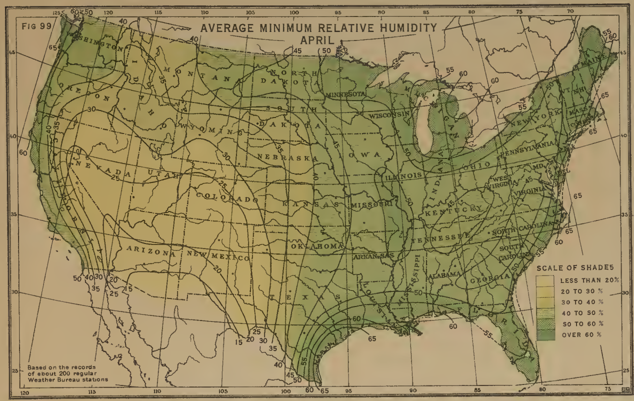


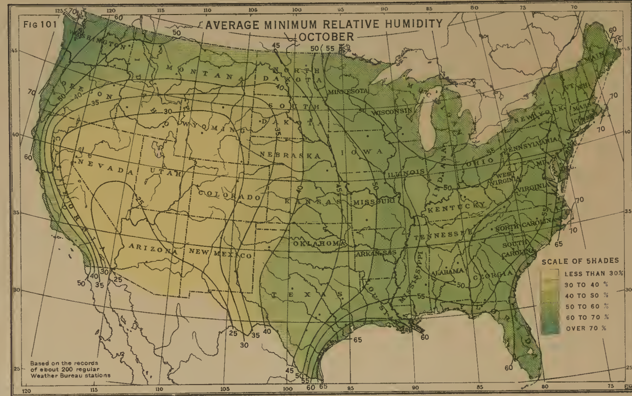


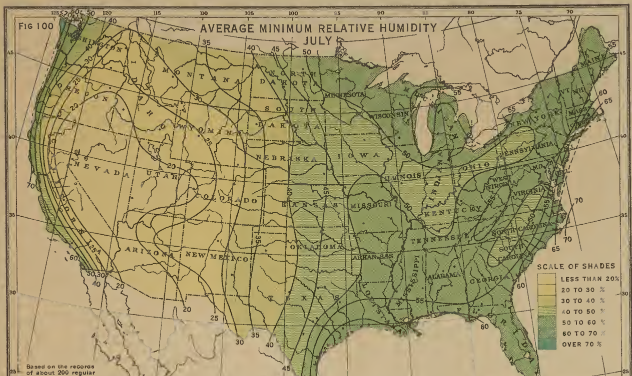


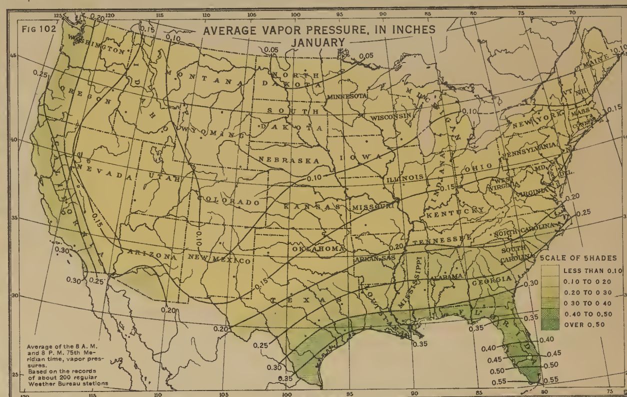


Figures 95 to 98 show the average relative humidity at 8 p. m., 75th meridian time, in January, April, July, and October. The seasonal variations in relative humidity follow no definite law, but in general for districts east of the Rocky Mountains the atmosphere is relatively driest in the spring, in April as a rule, while to the westward the lowest relative humidity occurs in midsummer. The highest relative humidity occurs usually in winter, except in the Southeastern States, where the maximum frequently occurs in the late summer or early fall. Geographically, the lowest relative humidity is found at all seasons of the year in the far Southwestern States, and the highest along the North Pacific Coast and in other regions contiguous to large bodies of water, especially those located on the leeward side. In most elevated regions the relative humidity is also comparatively high, with small diurnal and seasonal variations.

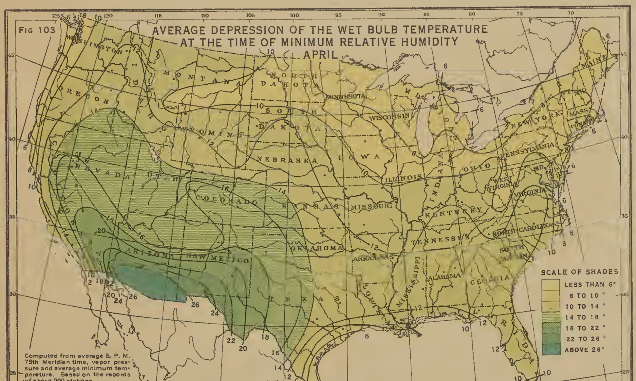


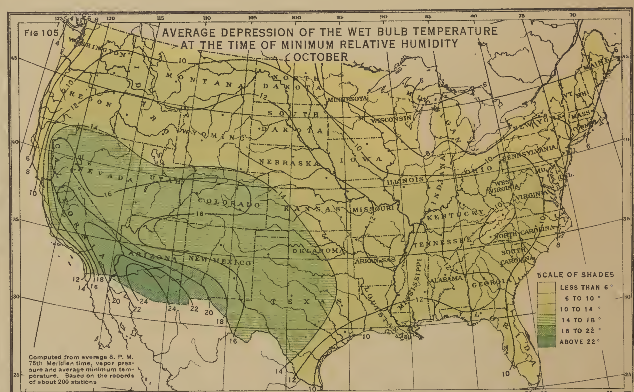


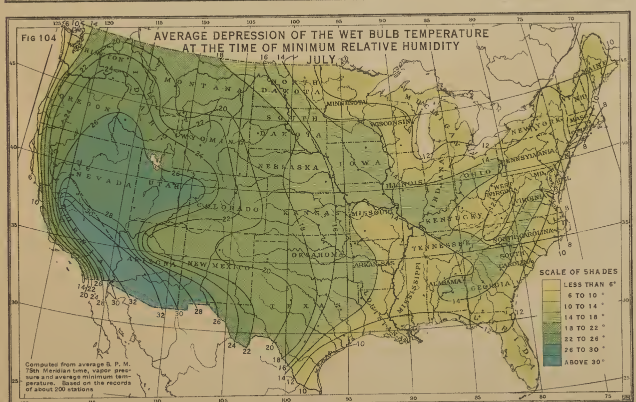


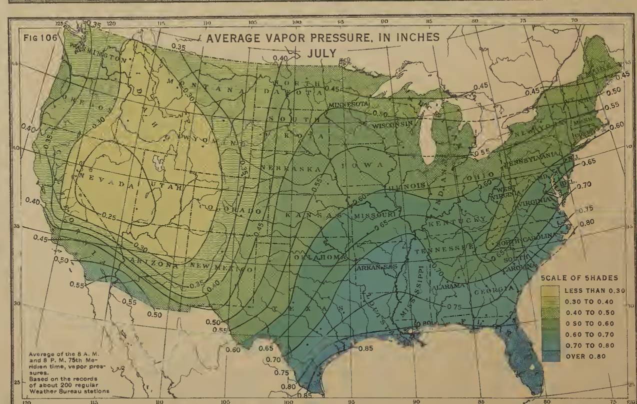


Figures 99, 100, and 101 show for the months of April, July, and October, the average daily minimum relative humidity computed from the average 8 p. m., 75th meridian time, vapor pressure, and the saturation pressure corresponding to the average daily maximum temperature. This is made possible by the fact that diurnal variations in vapor pressure are small and the 8 p. m. values do not differ much from the averages at the time of maximum temperature. No effort was made to compute these values for January because the large fluctuations in temperature from day to day in winter and the frequency of temperatures below the freezing point, render computations of this character of doubtful accuracy. Except at a few stations where hygrograph records have been made in recent years, no direct observations of the daily minimum relative humidity have been made by the Weather Bureau, hence the approximate values shown on these charts have been computed by the method indicated. The lowest relative humidity of the day occurs, as a rule, at about the time of maximum temperature, and the maximum relative humidity at about the time of minimum temperature. Figure 102 shows for the month of January the average absolute humidity as measured by the mean of the vapor pressure at 8 a. m. and 8 p. m., 75th meridian time. This mean does not differ much from the 24-hour average. In January the absolute humidity throughout the United States, except in Florida and along the Gulf Coast, is low, owing principally to the low temperature, being no greater than that in the Arid Interior Plateau in July (see fig. 106). The minimum in January, 0.05 inch, is in North Dakota, and the maximum, 0.55 inch, is in southern Florida.









Figures 103, 104, and 105 show for the months of April, July, and October the average depression of the wet-bulb temperature at the time of daily minimum relative humidity, which time corresponds closely to that of the maximum temperature. The values were computed from the average vapor pressure at 8 p. m., 75th meridian time, and the average daily maximum temperature. The high summer temperatures in arid and semi-arid climates are not so oppressive as indicated by the temperature records alone, since the dryness of the atmosphere affords increased opportunity for evaporation. In the far Southwest the wet-bulb temperature during the hottest part of the day in summer is often more than 30 degrees lower than the dry-bulb temperature; while at localities in the Great Lakes region it is less than 6 degrees. Figure 106 shows for the month of July the average absolute humidity as measured by the mean of the vapor pressure at 8 a. m. and 8 p. m., 75th meridian time. This mean does not differ much from the 24-hour average. In most of the United States, especially east of the Rocky Mountains, the geographic variations in the actual amount of moisture in the atmosphere, as shown by the vapor pressure, conform closely to those of temperature, decreasing from south to north and from summer to winter (see fig. 102). The minimum in July, 0.25 inch, is found in the Interior Plateau region, and the maximum, about 0.85 inch, occurs along the western Gulf Coast.

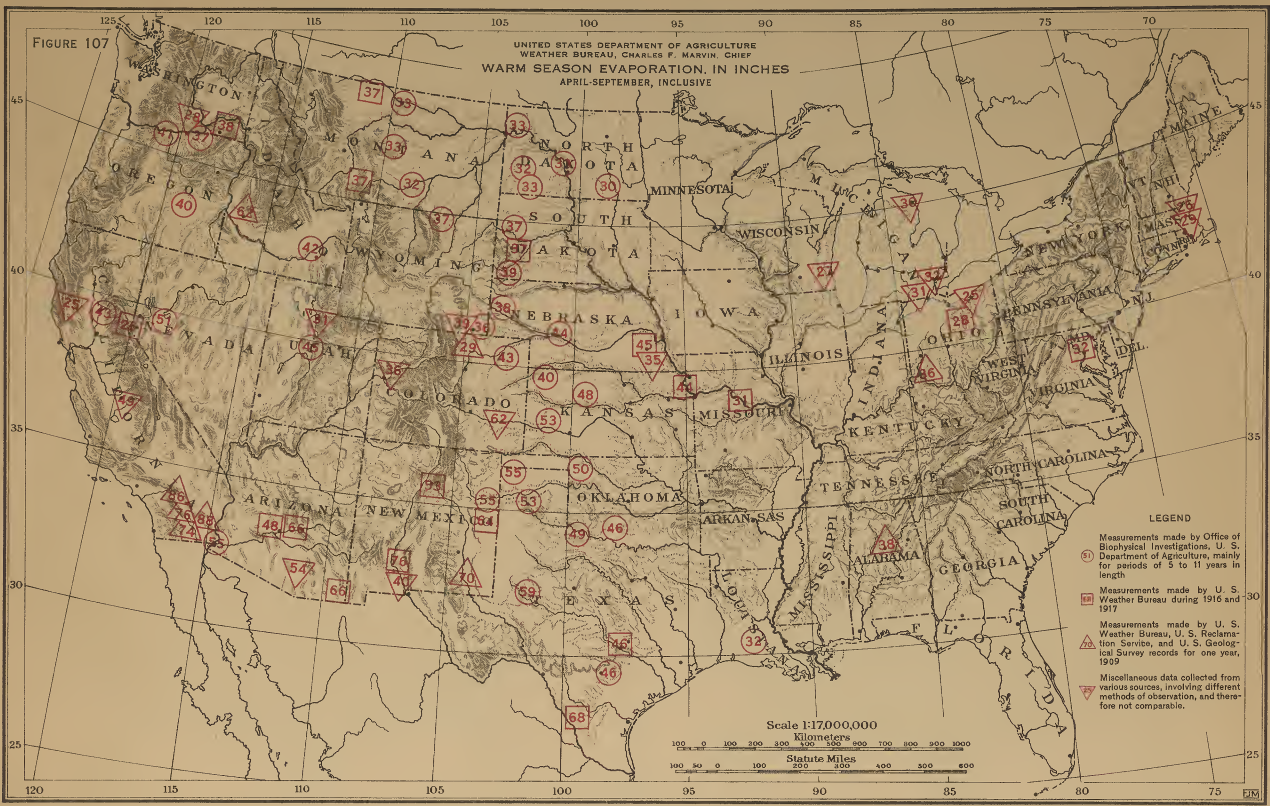


Figure 107 shows for a number of points in the United States the total evaporation, in inches, during the warm season, April to September, inclusive. The most extensive series of such observations are those made by the Office of Biophysical Investigations, Bureau of Plant Industry, in connection with their experimental work in the dry-farming regions of the West, and by the Weather Bureau. The observations by the Office of Biophysical Investigations were made from cylindrical pans 6 feet in diameter and 2 feet deep, sunk into the ground 20 inches, with the water level maintained at the height of the surface of the ground. Those made by the Weather Bureau were from cylindrical pans 4 feet in diameter and 20 inches deep, resting on a support, with the bottom of the pan about 6 inches above the surface of the ground. Evaporation from the Weather Bureau pans is somewhat greater than from those of the Bureau of Plant Industry, other things being equal, but data for each series are directly comparable among themselves. Of the two methods of exposure, that of the Bureau of Plant Industry probably more nearly represents actual evaporation from the soil, while the Weather Bureau method gives results typical of the meteorological conditions existing near the earth's surface. Records marked ○ are the average of observations, mostly 5 to 11 years in duration, made by the Office of Biophysical Investigations; those marked ▭ were made by the Weather Bureau during 1916 and 1917; those marked △ were collected by the Weather Bureau, U. S. Reclamation Service, and U. S. Geological Survey, and include only one year, 1909–10; while records marked ▽ were collected from various sources. Since different methods of observations were employed in securing the data on the map and in some cases different years are represented, the records are not directly comparable among themselves.

EVAPORATION.

In a study of the amount of rainfall usually received in a locality and its relation to agriculture, the question of loss of soil moisture by evaporation becomes of much importance, especially in regions where the available moisture supply borders on the minimum limit for the successful production of crops by ordinary methods of farming. The rate of evaporation of moisture from the soil depends principally upon the amount of moisture present, the soil texture, and the temperature, wind movement, and relative humidity of the atmosphere. Owing to the large variations in these several factors which control evaporation, and also to the varying rate of soil moisture loss by transpiration of plants and otherwise, a determination by direct observation of soil moisture loss by evaporation becomes of difficult accomplishment, and no extensive data showing this loss directly are available. Evaporation from a free water surface, however, gives some indication of the relative loss from the soil for different localities and considerable data of this nature are available, but unfortunately they were not all obtained under a uniform system of observational methods and consequently are not directly comparable. The rate of evaporation varies greatly for different kinds of atmometers and also with different exposures.

Figure 107 and Tables 1, 2, 3, and 4 show for a number of points in different sections of the country the amount of evaporation from a free water surface for the warm season, April–September, the source of the data and the observational methods used being indicated in each case. The available data in the eastern United States are scanty, but the stations are fairly numerous in the Great Plains region, where evaporation is of greater importance owing to the comparatively small amount of rainfall.

The increase in the amount of evaporation over the Great Plains region is pronounced with progress southward from the Canadian border, the amount being nearly twice as great in western Texas as in western North Dakota. The agricultural significance of these facts stated in terms of actual equivalent rainfall for the northern and southern portions of the Great Plains can only be approximately determined, since the influence of other factors, such as seasonal distribution of the rainfall in the southern portion and the more frequent torrential character of the precipitation, as compared with the northern portion, can not be separated from the effects of increased evaporation, but from some investigations that have been made it is concluded that from an agricultural standpoint 20 inches of annual rainfall in eastern North Dakota is equivalent to about 30 inches in southern Texas. It is interesting to observe the agricultural operations along a given isohyet. The 20-inch line of average annual precipitation extends in a north to south direction through the Great Plains region, conforming roughly to the 100th meridian of west longitude. This line in North Dakota passes through a region where the amount of moisture is usually ample for the successful production of wheat, oats, timothy hay, and other crops characteristic of a humid type of agriculture, but in Texas it passes through a country devoted largely to grazing and the growing of crops recognized as drought resistant, such as Kafir and milo.

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AVERAGE WARM-SEASON EVAPORATION.

TABLE 1.—*Summary of measurements, in inches, made by the Office of Biophysical Investigations, United States Department of Agriculture.*

Station.	Number of years in record.	April.	May.	June.	July.	August.	September.	Average total, Apr.-Sept.
Yuma, Ariz	9	7.76	9.54	10.58	10.21	9.61	7.43	55.13
Biggs, Calif	4	4.47	6.25	8.64	9.60	8.15	6.38	43.49
Akron, Colo	10	4.96	6.40	7.88	9.09	7.87	6.48	42.68
Aberdeen, Idaho	6	4.61	6.07	8.46	9.65	7.70	5.58	42.07
Colby, Kans	4	4.35	5.90	7.48	8.69	7.47	6.02	39.91
Garden City, Kans	10	6.50	8.58	9.89	10.91	9.51	7.46	52.85
Hays, Kans	11	6.16	7.04	8.42	9.97	9.29	7.02	47.90
Crowley, La	7	4.85	5.69	6.18	5.72	5.36	4.54	32.34
Havre, Mont	2	3.28	5.51	5.55	7.98	6.40	3.88	32.60
Huntley, Mont	7	3.24	4.56	5.89	7.55	6.67	4.32	32.23
Moccasin, Mont	9	3.83	4.93	5.56	6.78	7.06	4.62	32.78
Mitchell, Nebr	7	4.83	6.16	7.43	7.97	6.80	5.26	38.45
North Platte, Nebr	11	5.68	6.55	8.14	9.11	8.06	6.11	43.65
Fallon, Nev	10	6.21	8.09	9.92	10.78	9.74	6.58	51.32
Tucumcari, N. Mex	6	7.23	9.72	10.89	10.84	9.26	7.44	55.38
Dickinson, N. Dak	10	4.04	4.64	6.25	6.80	5.98	4.08	31.79
Edgeley, N. Dak	11	3.60	4.71	5.30	6.40	5.53	4.02	29.56
Hettinger, N. Dak	7	4.16	4.93	6.40	7.45	5.91	3.92	32.77
Mandan, N. Dak	5	3.78	5.15	6.06	7.37	6.45	4.49	33.30
Williston, N. Dak	8	4.31	5.52	6.39	7.08	6.05	3.76	33.11
Lawton, Okla	3	6.60	6.65	8.48	8.97	8.20	6.66	45.56
Woodward, Okla	4	6.38	7.51	9.43	10.84	8.54	6.82	49.52
Burns, Oreg	4	3.84	5.76	7.29	9.27	8.49	5.68	40.33
Hermiston, Oreg	6	4.03	5.48	7.47	8.47	6.82	4.38	36.65
Moro, Oreg	7	4.54	6.27	8.01	9.35	8.54	4.28	40.99
Ardmore, S. Dak	5	3.81	5.24	7.21	8.71	7.56	6.06	38.59
Newell, S. Dak	10	4.23	5.57	6.99	8.43	6.93	4.85	37.00
Amarillo, Tex	11	7.03	8.79	10.17	10.38	9.11	7.23	52.71
Big Springs, Tex	3	7.40	10.03	12.72	11.65	9.88	7.32	59.00
Chillicothe, Tex	5	6.48	7.90	8.98	10.14	9.11	6.30	48.91
Dalhart, Tex	10	7.49	9.52	10.56	10.61	9.63	7.58	55.39
San Antonio, Tex	11	5.70	6.69	8.69	9.61	9.01	6.35	46.05
Nephi, Utah	10	4.56	6.16	8.78	9.52	9.23	6.36	44.61
Archer, Wyo	5	3.65	5.06	7.17	7.95	6.88	5.63	36.34
Sheridan, Wyo	1	3.14	4.91	5.82	9.81	7.85	5.14	36.67

TABLE 2.—*Summary of evaporation measurements, in inches, made by the Weather Bureau, United States Department of Agriculture.*

Station.	Year.	April.	May.	June.	July.	August.	September.	Total, April-September.
Mesa, Ariz	1917	6.52	7.48	8.48	9.57	9.13	6.92	48.10
Roosevelt Reservoir, Ariz	1916	8.56	12.38	14.77	13.38	11.55	9.63	70.27
	1917	7.74	10.12	13.23	13.48	12.09	9.57	66.23
Wilcox, Ariz	1917	10.55	11.58	13.94	11.68	10.01	8.64	66.40
Yuma, Ariz	1917	6.80	8.48	5.77	9.32	11.51	7.79	49.67
Tahoe, Calif	1916	......	......	......	5.24	5.66	4.59	......
	1917	2.13	2.54	4.13	5.70	6.02	5.98	26.50
Washington, D. C. (American University)	1915	......	6.04	6.58	7.05	5.17	4.37	......
	1916	4.64	6.28	5.83	5.95	5.17	4.38	32.25
	1917	......	5.86	6.27	6.49	6.37	3.50	......
Arrowrock, Idaho	1916	......	......	......	8.86	8.53	6.14	......
	1917	......	4.42	7.52	10.17	......	5.53	......
Manhattan, Kans	1917	5.68	5.70	8.66	11.06	7.01	5.44	43.55
Gardiner, Me	1915	......	......	3.78	4.00	4.33	3.40	......
	1916	......	......	......	4.52	4.43	4.30	......
	1917	......	3.33	3.83	5.76	4.24	3.19	......
Columbia, Mo	1916	3.45	4.99	5.16	7.52	6.54	3.84	31.50
	1917	3.58	4.45	6.26	7.28	5.49	3.81	30.87
Bozeman, Mont	1917	1.92	5.90	7.07	9.49	8.07	4.84	37.29
Valier, Mont	1917	2.76	5.40	6.99	10.84	8.06	3.28	37.33
Lincoln, Nebr	1917	6.18	5.71	9.27	10.52	7.53	5.41	44.62
Elephant Butte Dam, N. Mex.	1916	......	15.47	16.87	11.83	9.55	9.11	......
	1917	12.92	13.50	15.29	13.25	11.81	9.00	75.77
Santa Fe, N. Mex	1916	......	......	11.71	8.21	6.93	6.48	......
	1917	7.22	7.64	11.89	9.96	9.04	6.79	52.54
Tucumcari, N. Mex	1917	9.34	9.40	13.44	13.76	10.46	7.20	63.60
Wooster, Ohio	1916	......	......	......	6.18	6.41	4.72	......
	1917	2.86	4.12	5.04	5.73	6.61	3.60	27.96
Rapid City, S. Dak	1916	......	......	5.24	4.96	8.07	5.98	......
	1917	2.56	4.07	7.01	10.18	7.61	5.12	36.55
Austin, Tex	1916	6.88	8.09	8.53	7.82	7.46	6.84	45.62
	1917	7.28	7.44	10.50	9.96	11.02	......	......
Laredo, Tex	1917	10.91	10.18	11.72	13.67	13.15	8.76	68.39
Walla Walla, Wash	1916	......	......	6.16	7.52	8.34	5.61	......
	1917	3.31	4.45	6.34	9.54	9.28	5.01	37.93

TABLE 3.—*Data collected by the U. S. Weather Bureau, U. S. Reclamation Service, and U. S. Geological Survey, comprising one year's record 1909–10. (See Abstract of Data No. 4, U. S. Weather Bureau.)*

Station.	Diameter of pan in feet.	Total, April–September.	Station.	Diameter of pan in feet.	Total, April–September.
Birmingham, Ala	4	38.3	Mecca, Calif	6	76.5
Brawley, Calif	6	73.8	Deer Flat, Idaho	3	61.6
Indio, Calif	6	86.5	Carlsbad, N. Mex	4	69.7
Mammoth, Calif	6	88.2	California, Ohio	4	35.5

TABLE 4.—*Miscellaneous data (see Bul. 188 Bureau of Plant Industry).*

Station.	Period covered.	Total, April–September.	Station.	Period covered.	Total, April–September.
Tucson, Ariz	1892–1894	54.2	Monroe, Mich	1863–1867	30.9
Kingsburg Bridge, Calif	1882–1885	49.2	Thunder Bay, Mich	1862–1865	30.2
Lakeport, Calif	1901–1902	25.3	Lincoln, Nebr	1899–1909	34.8
Fort Collins, Colo	1887–1902	29.3	Las Cruces, N. Mex	1899–1901	40.1
Grand Valley, Colo	1901	36.5	Cleveland, Ohio	1862–1867	24.6
Rocky Ford, Colo	1901	61.6	Fort Douglas, Utah	1890–1892	30.7
Boston, Mass.:			Prosser, Wash	1900–1901	27.6
Beacon Hill	....	25.8	Milwaukee, Wis	1863–1867	26.9
Chestnut Hill	....	28.6	Laramie, Wyo	1893–1898	39.4
Detroit, Mich	1861–1864	32.1			